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MEASUREMENT OF GAS WELLS AND OTHER GAS STREAMS.

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Advance Matter from the Forthcoming Report of Dr. EDWARD ORTON, State Geologist for Ohio, Professor of Geology, Ohio State University.

Some of the recently bored gas wells in Ohio are discharging gas at too high a rate to be measured conveniently with an ordinary gas anemometer, since the delicacy of the instrument is such that it cannot stand the violence of the current. To use it would require reduction of velocity by increasing the diameter of the stream of flowing gas from the well. This may be done by means of flaring tubes fastened to the well mouth, which, however, is attended with some cost and trouble, the avoidance of which is desirable. To this end I was invited by the State Geologist, Dr. Edward Orton, to consider the question of gas well measurement.

The correct measurement of such a gas stream, where the temperature, density and velocity are all unknown, appeared to be a matter of considerable difficulty, even when the anemometer could be applied, because that instrument could make known only one of the unknown quantities, viz.; the velocity. The density being still unknown, the weight of gas discharged per minute could not be determined; and as the well mouth temperature is also still unknown, the density at that temperature cannot be calculated, even if the specific gravity of the gas is known.

Among the various appliances which suggested themselves for application was the Pitot's tube, a shunt, Bunsen's effusion principle for density of shunted gas, and a thermometer enclosed in an open tube, nearly closed at the rear, to be presented as is the Pitot's tube.

On investigation, the Pitot's tube was found to give the value of the product of the density by the square of the velocity. Had it given the density and velocity both to the same exponent in the product, the weight per second could have been found by simply multiplying by the area of the well mouth; but that not being the case, it was necessary to find the density, or the specific gravity which will serve as well, in the well mouth, either directly or calculate it from that of the gas at ordinary conditions. Measuring the velocity by the anemometer would serve, but the use of this instrument was what was to be avoided. By using the shunt of known area of mouth, and storing the gas for a definite time of flow through the shunt, the gas being allowed to gain ordinary conditions, the weight or volume per second for the well could be found from the shunt alone by multiplying the weight or volume per second shunted by the ratio of areas of well mouth and shunt mouth.

This shunt device was therefore considered favorably, until some experimental

measures were made. But the testing of the devices showed that the shunt could not be relied upon generally, for the reason that the gas sometimes carries oil from the well, which oil would smut the shunt orifice and modify to an unknown degree, the effective area of the shunt mouth, and correspondingly vitiate the results in such cases. In the Pitot's tube tests the instrument was found to be thoroughly reliable for what it gave, regardless of the heterogeneity of the fluid flowing; and the temperature of the gas could be estimated with some degree of approximation, since the pipes would sometimes freeze the water condensed upon them and sometimes not, at all the wells examined during the testing of the instruments. Also, the Pitot's tube, for convenience of application cannot be excelled, as the completion of an observation is but the work of a moment, regardless of condition of orifice. The encased thermometer was not applied at gas wells, though it has been well tested in connection with Westinghouse air apparatus.

As all these appliances will doubtless be found useful in the measurement of the streams of gas from gas wells, and of other gas currents, a description of each and the formulas for reduction of observations will be given.

THE PITOT'S TUBE.

This tube takes its name from the inventor, Pitot, who made it known to the French Academy of Sciences in 1732. See Morin's "Hydraulics," page 131. It is shown in all its simplicity and essential principles in Fig. 1, in position for determining the velocity of a current of water flowing along its bed with the free surface at b. The instrument, as here shown, consists simply of a plain piece of glass tube, L shaped, placed with an open mouth, a, presented directly toward the current, while the other end reaches above the surface at b. Now, when the water drives against the open end a, a pressure results from the impact, which causes the water to rise in the branch bc, to a height h, which height is to be used as a head by which, in some way, to calculate the velocity. Pitot concluded that this head was simply that due to the velocity v of the current, so that

$$v^2=2gh,$$

where g is the acceleration of gravity. This formula is that for falling bodies, and also that for Torricelli's theorem for the velocity of issue of water from an orifice.

According to this, when water is flowing from an opening in the side of a tank, if the mouth of the Pitot's tube, somewhat smaller than the jet, be presented square against the jet, the water would rise in the upright branch of the tube just to the level of the surface of the water in the tank. This simple device, therefore, furnishes us a very handy means for finding the velocity in a stream of water, provided the instrument is reliable for accuracy.

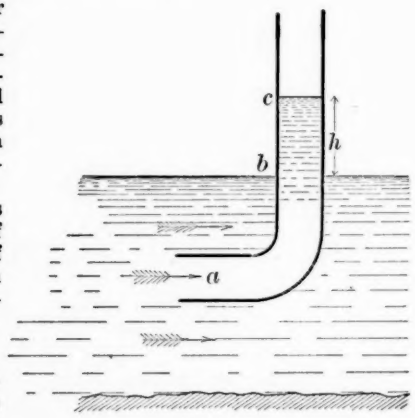


Fig. 1

For over one hundred years after its discovery, this device, so admirable for its simplicity, was regarded more for curiosity than utility, and it was believed not to be reliable for accuracy. See D'Aubuisson's "Hydraulics," (Bennett's translation) page 158. But about in 1850, M. D'Arcy, an able French hydraulic engineer, seeing in the Pitot's tube the rudiments of a most admirable hydraulic instrument, studied it with a view to reducing it to the most useful form and design for practical purposes, for a complete description of which, see Morin's "Hydraulique," page 133. The main features of this form consist of using two tubes side by side, extending from some distance above water down to de-

sired depth, then turning horizontally toward the current to where one tube terminated in a small mouth of one millimeter diameter presented direct, while the second tube was cut to a long slant and was joined upon the side of the first so as to form a smooth and converging exterior surface. Near the front termination of the second tube and about half an inch back from the open mouth of the first tube was a small hole laterally. The top ends of the tubes were glass and connected across, so that when water was drawn up by sucking the air partially from the tubes and closing a cock, the columns of water would stand at a height convenient for reading.

The instrument was thoroughly tested, and instead of being a mere toy, was found to be an instrument of precision. Also, as a more surprising fact, instead of requiring a large and varying correction factor, it was found to follow Pitot's originally stated principle exactly, viz.: $v^2=2gh$, where h is the difference of level of the tops of the two columns.

It is believed that this Pitot's tube appliance has been regarded as too simple to be reliable, from the fact that it has been so little used, whereas, its simplicity, instead of condemning it, should have commended it so far as to give it more trials than it has had, which, when thus tried, it is certain, would gain a high place in the estimation of the investigator.

A further modification in form and design of this instrument was made in 1877, a full description of which was given in VAN NOSTRAND'S MAGAZINE in vol. 18.

About in 1873, some interesting experiments were made by the writer on the use of the Pitot's tube for the determination of the velocity and form of jets of air from orifices under a head a of 2 to 4 inches of water, which experiments, as far as known to me, were the first in the application of Pitot's tube to gases. Orifices of 1 inch and 2 inches diameter were employed. The Pitot's tube in this case consisted of a glass tube about 2 feet in length bent twice at one end for an inverted U water manometer, while the other end was drawn out into a fine point, or mouth, of about five-thousandths of an inch diameter. The instrument was mounted on a slide so as to be moved by scale either across or lengthwise the jet. It is seen that by this arrangement the precise form of the longitudinal section of the jet and its velocity at any point of any cross-section could be made out. The stream was found to have a *vena contracta* much as in water jets, though shorter, and a velocity which varied from side to side in carrying the instrument across the jet, the maximum being at the middle, and very considerably higher than that at the side.

Most of the particulars respecting the jet are given in Fig. 2 for the 2-inch orifice AB, beveled to a sharp inner edge. The contracted section is near CD, and the length of the *vena contracta* is about a fourth of the diameter of the orifice, whereas in water jets, it is about a half to two-thirds. The diameter of the jet is given for every $\frac{1}{4}$ inch for the first inch, and then for the half inches. At 12 inches from the orifice, the jet was $4\frac{1}{8}$ inches in diameter. EF is the velocity curve, the velocities varying from 95 to 122 feet per second through the orifice, with the water manometer varying from 2 to 3.6 inches.

The most remarkable thing observed at this time was the fact that when the mouth of the instrument was extended some three or four inches into the tank by reaching the long neck provided on this Pitot's tube in through the orifice of issue of air under experiment, the pressure for which position being, of course, that of the interior, and then drawn slowly outward along near the middle of jet until the mouth of the Pitot's tube had reached a distance of one or two inches outside the plane of orifice of issue, the pressure indicated by the manometer was all the while precisely the same, the current through the orifice being all the while unobstructed. Here it seems certain that for mouth of tube within the tank the pressure by tube manometer is almost entirely statical, because the current here must be slight, and that at the outside of the plane of orifice the pressure indicated must be dynamic, or due to impact of air against end of tube mouth, and also that between these points there must have been a mixture of static and dynamic pressure. This strikingly illustrates the fact that as the internal pressure of a particle of fluid diminishes the stored energy increases, and that as the

potential energy due to the pressure falls the actual energy of motion rises, the sum of the two being a constant, for particles of fluid flowing through a frictionless orifice from a higher to a lower pressure. It also proves that the Pitot tube will exactly indicate a pressure or head due to velocity, when the statical pressure is eliminated, as done in the D'Arcy form of instrument. This form is that proper for use intermediate along a pipe or conduit carrying water, compressed air, or gas a considerable distance where there will be a considerable amount of statical pressure in the fluid. The latter will be eliminated in the D'Arcy form of instrument by the lateral orifice, the difference between the pressure there and at the front orifice being the dynamic pressure from which to find the velocity of fluid.

The general application of the Pitot tube to all fluids will involve consideration of variation of density of fluid under flow, so that formulas for invariable and also variable density will be required. For elastic fluids, the density will always vary, though for many cases, the variation will be so slight that it may be neglected. Thus at gas wells, when $h=4$ inches of water, the absolute pressure of the atmosphere into which the gas flows is about 400 inches, the variation of pressure being only one per cent., while in the Karg well where the pressure gauge of the Pitot's tube goes up to 15 lbs. per square inch (one atmosphere), the density will fall nearly 100 per cent. in expanding from the tube mouth to the atmosphere.

For low pressures, the apparatus shown in Fig. 3 will serve where A is the well mouth, or other orifice; BB, the Pitot tube; C, a piece of rubber hose; D, a glass tube; E, a second piece of rubber; and F, a second glass tube. Now, filling the part DEF with water from D to F, then it is plain that as a pressure is caused at B by impact of gas from the well, it will be transmitted to D, depressing D and raising F, giving a difference of level $DF=h=\frac{v^2}{2g}$.

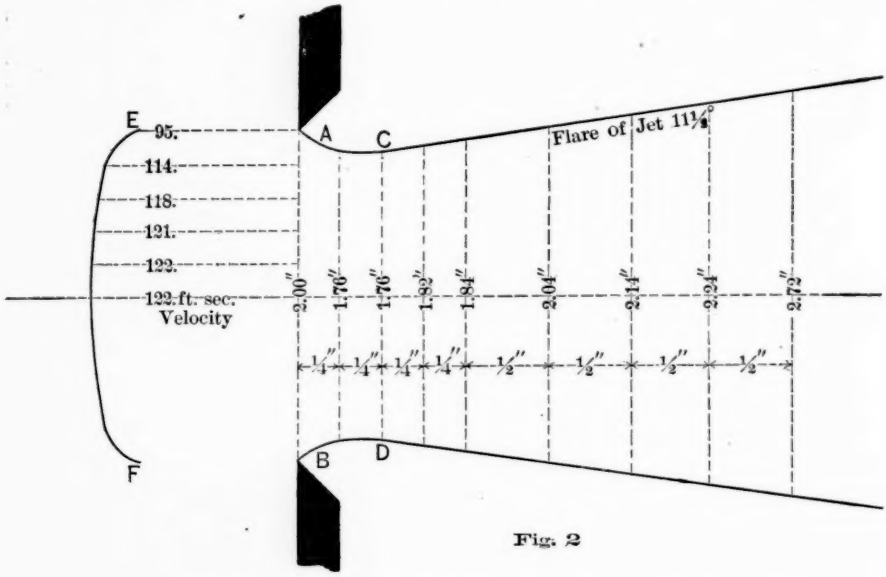


Fig. 2

By making E of some three feet length, the glass tubes can be raised F above D, as required for greater or less values of h. When h exceeds 3 or 4 feet, it will be advisable to use a pressure gauge on the end of B, as shown in Fig. 4. In use, it is advisable to pass the mouth of

B to all portions of the well opening, and thus average for the section.

If it be suspected that there be a residual statical pressure in the gas at the mouth of the tube B, it may be tested and eliminated, if existing, by using a double tip of B, with a direct and a lateral opening, one connected to the pressure side D, and the other to the vacuum side F, of the pressure measuring device. But according to all the best authorities on flow of gases through orifices, such as Weisbach, Rankine, Zeuner, etc., the internal residual statical pressure of a jet, on entering the atmosphere, or generally on flowing from a higher to

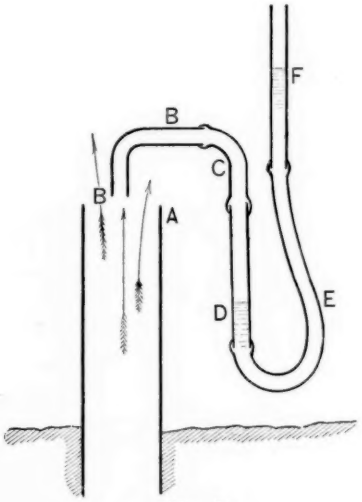


Fig. 3

a lower pressure, becomes the latter as soon as, or very soon after the plane of the orifice is passed. This fact is verified by placing the mouth end of B at right angles to and within the jet, when no appreciable pressure will be indicated.

The theory of the instrument for the case of great fall of pressure in flow of elastic fluids will be reassured, if even support is unnecessary, by citation of experiments recently made in flow of air from a receiver at 20 to 40 lbs. per square inch through an orifice to the atmosphere. Air was pumped into a Westinghouse air brake reservoir to about 40 lbs. and allowed to escape through a quarter-inch orifice beveled from the outside to the plane of the inside surface, thus securing the conditions of an orifice in a thin partition, or very nearly a theoretical orifice. An accurate pressure gauge graduated pound by pound was placed upon the receiver. A second gauge, duplicate of the first, was put on the Pitot tube, the mouth of which was 0.065 inch in diameter. The orifice was opened, and into the air stream the mouth of the Pitot's tube was placed, and the pressure of the two gauges noted simultaneously as the air escaped, and the pressure run down. The gauges kept exactly together,

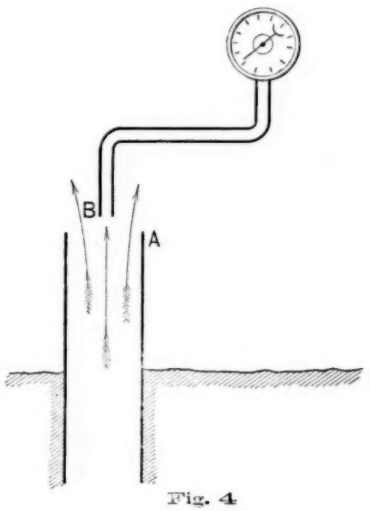


Fig. 4

as long as the Pitot tube mouth was fairly within the current and not over one and a-half diameters of orifice distant from the orifice.

Three other like experiments were made and noted, the figures for which are given in the following table. The mouth of the Pitot tube, in each case, reached about an inch into the receiver, and then was withdrawn step by step, as the pressures were noted, the note "at orifice," meaning that the tube mouth was at the plane of orifice, and "$\frac{1}{8}$" out," meaning one-eight inch outside of plane of orifice but always in the jet.

TABLE OF SIMULTANEOUS RECEIVER AND PITOT TUBE PRESSURES.

First Experiment.

Receiver	Tube	
30	29½	
26½	26½	
24	24	
22	22½	at orifice.
20	19½	out.
18	17½	

Second Experiment.

Receiver	Tube	
27½	26⅝	
24½	24	
21	21	at orifice.
20	19½	⅛″ out.
17	15½	⅜″ out.
16½	14	¾″ out.

Third Experiment.

Receiver	Tube	
28	27½	
25	24½	
22½	22½	at orifice.
20½	20½	⅛″ out.
18	16½	7/16″ out.
16½	13	1″ out.

These figures show that the pressure in the receiver and that in the Pitot tube agree with practical exactness, as the mouth of the Pitot tube is withdrawn from the position extended an inch within until the mouth is over ⅛ inch outside (a diameter by other experiments and probably the same here, viz.: ¼ inch); and that when the tube mouth is four diameters outside, its pressure is up to ¾ that of the receiver. Besides this, in determinations of tube pressure at gas wells, it was found that the same pressure was got whenever the mouth of the tube ranged within a diameter of well mouth in distance from it.

In the above experiments, the jet of air was forced direct and square against the Pitot tube mouth when outside, so that the cause of the pressure was wholly dynamic, and not at all static; that is, that at points just in front of the orifice, there is no residual statical pressure. Experiments were made to test this point by making a D'Arcy form of double mouth Pitot tube, one mouth being direct as before, and the other on the side of the tip, as shown in Fig. 5, at A and B respectively. Small holes were drilled back from the mouths A and B, and entirely independent of each other and connected at the rear, one with one standard gauge at C, and the other with another at D, all combined into a portable device.

Now, the mouth A will communicate

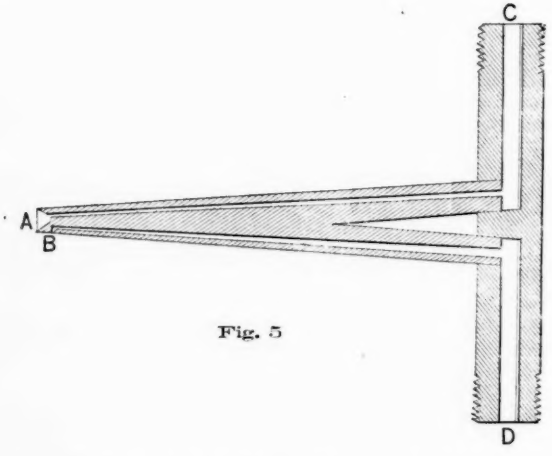


Fig. 5

the pressure due to direct impact, while at B, the moving fluid will tend to move straight by, and will cause no action at

B, except for the lateral statical pressure of the jet at the point B, as concluded by D'Arcy for his improved tube for gauging streams of water.

This tip AB, Fig. 5, was inserted to some distance through the orifice into the receiver and then withdrawn step by step, until some distance outside; and the indications by both gauges noted simultaneously at the steps, where the tip was held steady for a few seconds.

When AB is within the receiver, the two gauges should, of course, indicate nearly the same, while when outside, the gauge for B should stand at zero. Results of test are given in the following table:

Table of Simultaneous Direct and Side Mouth Pitot Tube Pressures, to Test for Statical Pressure of Jet.

Distance of Side Outlet from Plane of Orifice.	Pressure by Gauge connected with Mouth.							
	1st Experiment.		2d Experiment.		3d Experiment.		4th Experiment.	
	Direct.	Side.	Direct.	Side.	Direct.	Side.	Direct.	Side.
Inside, $\frac{3}{8}$-inch.....	24	25	26	27	—	—	—	—
" $\frac{1}{4}$ "	22	23	24	25	22	23	—	—
" $\frac{1}{8}$ "	20	21	22	23	20	23	21	22
At orifice.....	17	18	20	19	19	20	20	19
Out, $\frac{1}{16}$-inch.....	—	—	—	—	17	15	18	13
" $\frac{1}{8}$ "	14	0	19	1	16	0	16	0
" $\frac{1}{4}$ "	12	0	15	0	14	0	15	0

In examining this table, consider the 3d experiment for instance. When the side mouth B was a quarter of an inch inside the receiver, the gauge for that mouth indicated 23 lbs. per square inch, while the gauge for the direct mouth A indicated 22 lbs. When B was at the plane of the orifice its gauge stood at 20, and that for A, at 19 lbs. For B $\frac{1}{16}$-inch outside the plane of the orifice its gauge stood at 15 lbs., and that for A at 17 lbs. Again, for B $\frac{1}{8}$-inch outside, its gauge stood at zero, while that for A stood at 16 lbs.; the lateral pressure, or statical pressure, of jet vanishing entirely within the space of a sixteenth of an inch, which space lies about at the terminus of the *vena contracta*, or about at CD, Fig. 2.

Hence the two gauges practicably agree within the receiver, and that for B falling from agreement with A, at the plane of the orifice, to zero at the contracted section; at which latter section, therefore, there is no residual statical pressure. In cases where there is no *vena contracta*, as for the cylindrical ajutage, for instance, or the mouth of cylindric pipes, there can be no residual statical pressure at the plane of the exit mouth, the contracted section in this case.

The fall of pressure from 22 to 14 for the direct mouth A of the 3d experiment was not due to the withdrawal of the tube from the receiver, nor in any other experiment; but the fall was owing to the exhaustion of the receiver of air on account of the flow; the pump not being able to maintain pressure.

From all the above facts of experiment for high and low pressures we are forced to the conclusion that the Pitot tube is a thoroughly reliable instrument for determining the pressure or dynamic head to which the velocity of flow is due, and that the original notions announced by Pitot respecting the relation of velocity and head are rigorously substantiated, not only for flowing water, as he announced, or even other liquids, but for all kinds of fluids, elastic as well as inelastic, except, possibly, for viscous fluids like molasses or tar.

It appears, then, that in calculating the velocity of flow from a receiver, the pressure to be used for head may just as well be taken from the Pitot tube as from the receiver direct, and the same formula is to be used for the one as for the other. Hence, where there is no receiver to

gauge from, we may proceed with the Pitot tube.

VELOCITY UNDER SMALL PRESSURES.

To calculate the velocity of flow for fluids where the change of density during flow can be neglected, we employ the formula of Pitot, but for gases, the head h must be found on the supposition that h is the depth of the gas from the orifice up to an imaginary free surface throughout which the density is uniform and the same as at the orifice. Then the pressure per unit surface upon the orifice will be

$$p_1-p_2=\delta h \text{ or } h=\frac{p_1-p_2}{\delta} \qquad (2)$$

where δ is the specific density of the fluid flowing, or the weight per cubic unit. Thus, for air flowing from a receiver where the absolute pressure is p_1 into a space where the absolute pressure is p_2, the effective pressure will be p_1-p_2, as above. Hence

$$v^2=2g\frac{p_1-p_2}{\delta} \qquad (3)$$

a general formula for case of slight variation of δ.

At the mouth of a gas well the pressure of the gas flowing is the atmospheric and its density is

$$\delta=.0807\ \mathrm{S}g.\frac{\tau_0}{\tau} \qquad (4)$$

where $\mathrm{S}g.$ is the specific gravity of the gas, air being 1, τ_0=the absolute temperature of melting ice, and τ the absolute temperature of the flowing gas. But

$$\frac{\tau_0}{\tau}=\frac{273}{273+t}\text{Cent.}^\circ=\frac{493}{461+t}\text{Fahr.}^\circ$$

Introducing these into the Pitot formula and taking $2g=64.3$, we get for units in feet,

$$v=338.7\left(1+\frac{t}{546+t}\right)\sqrt{\frac{p_1-p_2}{\mathrm{S}g.}},\text{Cent.}^\circ$$

$$=338.7\left(1+\frac{t-32}{954+t}\right)\sqrt{\frac{p_1-p_2}{\mathrm{S}g.}},\text{Fahr.}^\circ \qquad (5)$$

where t is the temperature of the flowing gas.

Applying this to a gas well, p_1-p_2 is the effective pressure indicated by the pressure gauge, and taking the temperature at the freezing point and $\mathrm{S}g.$ at 0.6 for an approximation, we have

$$v \text{ approx.}=437.3\sqrt{p_1-p_2} \qquad (6)$$

Suppose the pressure gauge on the Pitot tube reads 1 lb. Then $p_1-p_2=1$ *lb.* and $v=437.3$ feet per second.

For small pressures, such that the water manometer is used, as in Fig. 2, 1 lb. pressure is equivalent to 27.5 nearly inches of water, and by putting h the head in inches of water, we have.

$$p_1-p_2=\frac{h}{27.5},$$

$$v=64.37\left(1+\frac{t}{546+t}\right)\sqrt{\frac{h}{\mathrm{S}g}}\text{ Cent.}^\circ$$

$$=64.37\left(1+\frac{t-32}{954+t}\right)\sqrt{\frac{h}{\mathrm{S}g}}\text{ Fahr.}^\circ \qquad (7)$$

and taking $\mathrm{S}g=0.6$,

$$v \text{ approx.}=83.1\sqrt{h} \qquad (8)$$

Suppose the manometer gives 27.5 inches of water, =1 lb. pressure. Then (8) gives $v=437.3$ feet per second.

VELOCITY UNDER GREAT PRESSURES.

When a gas flows from a receiver into a space outside with a relativeiy large fall of pressure, the formulas for adiabatic flow of gas are to be employed for calculation. The correct formula for this is found in most of our best authorities, viz.:

$$v^2=\frac{2\,g\,\gamma}{\gamma-1}\frac{p_2}{\delta}\left\{\left(\frac{p_1}{p_2}\right)^{\frac{\gamma-1}{\gamma}}-1\right\} \qquad (9)$$

in which, for the present use, p_1=absolute pressure by Pitot's tube gauge; p_2= absolute pressure of air = 14.6 lbs. per square inch; δ=wt. unit vol. of flowing gas at mouth of Pitot tube=$.0807\frac{\tau_0}{\tau}\mathrm{S}g$; τ_0 and τ=absolute temperatures, as before, $\mathrm{S}g$=specific gravity of flowing gas at mouth of Pitot tube, air=1; $\gamma=1.408$; $\frac{\gamma}{\gamma-1}=3.451$; $2g=64.3$; m^3=value in parenthesis: then, introducing the numerical values and reducing, we obtain;

$$v=2404\frac{m}{\sqrt{\mathrm{S}g}}+\frac{t}{546+t}2404\frac{m}{\sqrt{\mathrm{S}g}},\text{ for Cent}^\circ$$

and

$$v = 2404\frac{m}{\sqrt{Sg}} + \frac{t-32}{954+t}\,2404\frac{m}{\sqrt{Sg}} \text{ for Fahr.}^\circ \qquad (10)$$

If the temperature of the flowing gas be taken at that for melting ice and Sg at 0.6, we obtain the approximate formula

$$v \text{ approx.} = 2404m \qquad (11)$$

To facilitate the calculations with these formulas, the value of m in terms of the ratio of pressures p_1 to p_2 may be tabulated as follows:

$\frac{p_1}{p_2}$	m.	m^2.
1.035	.1000	.01
1.071	.1414	.02
1.107	.1732	.03
1.145	.2000	.04
1.183	.2236	.05
1.222	.2449	.06
1.263	.2646	.07
1.304	.2828	.08
1.346	.3000	.09
1.389	.3162	.10
1.433	.3317	.11
1.478	.3464	.12
1.525	.3606	.13
1.572	.3742	.14
1.620	.3873	.15
1.669	.4000	.16
1.719	.4132	.17
1.770	.4243	.18
1.822	.4359	.19
1.876	.4472	.20
1.930	.4585	.21
1.986	.4690	.22
2.043	.4799	.23
2.101	.4899	.24
2.160	.5000	.25

The bracketed quantity in equation (9) may be put in the form

$$\left\{\left(1+\frac{p_1-p_2}{p_2}\right)^{\frac{\gamma-1}{\gamma}}-1\right\}.$$

Developing by the binomial theorem, and (9) becomes

$$v^2 = 2g\frac{p_1-p_2}{\delta}\left[1-\frac{p_1-p_2}{2\gamma p_2}+\frac{\gamma+1}{6\gamma^2}\frac{(p_1-p_2)}{p_2}-\&c.\right] \qquad (12)$$

the first term of which is the same as (3), and the remaining terms may be regarded as corrections to (3), modifying it as required for the change from constant to varying density under flow. From this it is seen that for adiabatic flow, the formula for constant density gives values which are too high.

CONFIRMATION OF THE FORMULAS.

The shunt has been used to verify results by the Pitot tube in the flow of air and of gas under variable density.

1. For air, the Westinghouse Reservoir was charged with compressed air to 17 lbs. per square inch, and the one-fourth inch orifice opened for discharge, while the shunt mouth was introduced into the issuing jet for eight seconds and the pressure noted for every two seconds as follows:

VERIFYING EXPERIMENT WITH SHUNT.

Seconds.	Receiver Pressure.	Means by Pairs.	Calculated Velocities.
0	17		
		16.50	1115
2	16		
		15.75	1083
4	15½		
		15.25	1070
6	15		
		14.75	1056
8	14½		

Mean velocity, ft. per sec., calculated 1081
Velocity by the shunt," " 1006

The shunt orifice was 0.065 inch diameter, and the shunted air was 40.08 cubic inches per second. The shunt orifice (explained later) was one of no resistance, and the gas bag and connecting pipes offered no appreciable resistance. The shunt orifice, however, could never have a greater effective area than that measured, while slight traces of dust would make it less. The possibility of some lingering dust and the resistance of connections would account for part of the difference of velocities 1081 and 1006 observed.

It is to be observed that the shunt is theoretically a positive measurer of velocity, so that the 1,006 feet may be regarded as positively not far from, though probably less than the actual velocity.

Hence the 1,083 feet velocity given by the Pitot tube calculation is to be regarded as a fairly reliable result.

2. At a gas well the Pitot tube and shunt were both applied in quick succession, each several times, with mean results as follows:

Velocity by tube=1178 feet per second.
" " shunt=1111 " "

The shunt mouth was cleaned out each time applied, to clear it of possible obstructions, though no evidence was found of interfering matter.

3. At a second gas well the results were as follows:

Velocity by tube=1,016 feet per second.
" " shunt= 876 " "

This well carried traces of oil along with the gas, so that the hand placed in the jet in a few seconds would be smutted with oil. Hence, there can be no doubt but that the oil deposit in the shunt mouth noticed at the time had a very appreciable effect in cutting short the flow by shunt. This discrepancy of results is therefore expected, and that fact here serves for verification.

PITOT TUBE MOUTH.

By regarding the pressure obtained by this instrument as due to the impact against the open mouth, it is easily seen that the amount of action is proportional to the area of mouth, so that this area is independent of the observed pressure. In the experiments, the largest mouth was $\frac{7}{16}$-inch, another was $\frac{1}{4}$-inch, and the smallest was 0.065 inch in diameter, giving the following results at the Karg gas well where all were tried:

TEST FOR SIZE OF TUBE MOUTH.

	Mouth 0.065 inch diameter.	Mouth $\frac{1}{4}$-inch diameter.	Mouth $\frac{7}{16}$-inch diameter.
1, side.....	12	13	—
2.....	14	15	14.5
3, center....	15.5	15	15
4.....	14	14.5	10
5, side.....	9	9.5	—

Each figure in the table is the mean of two observations. The observed pressures agree well for the different sizes, and indicate absolute independence of size of tube mouth.

The small mouth is the one used for the shunt. All were formed sharp, or very nearly so, at the front end of tube around the mouth, and no experiments were made with a dull mouth rim.

THE SHUNT.

A shunt properly constructed for this purpose should offer no resistance to the movement of the fluid, so that when a particle of shunted gas has just fairly entered the shunt mouth, its velocity should be the same as that of the stream around it.

The connecting tube, for as great a portion of length as possible between mouth and collecting bag, should be large, and yet it should be gradually enlarged from the point or mouth in order not to present a blunt end for impact of gas and thus modify the flow into its mouth.

To thus secure a tapering tip and at the same time an orifice of no resistance, the device of making the inside with a gradual flare for an inch or two was resorted to, and such a flare that the resulting loss of velocity and consequent loss of energy of motion in the passage would just compensate for the frictional resistance to be overcome in this small part of the passage. After thus getting a suitable distance from the mouth, a sudden enlargement was made to such size as to reduce the remainder of the connecting pipes to practically no resistance.

If v=velocity of fluid at the mouth end, and v' that at the larger end where the sudden enlargement occurs, then the loss of energy of motion between the points will be

$$\tfrac{1}{2}\mathrm{M}(v^2-v'^2)$$

where $\mathrm{M}=\dfrac{\delta a v}{g}$ per second.

δ being the density and a the area of passage way.

The work overcome in frictional resistance per second will be the force into the space.

$$\mathrm{F}v=f\delta\pi dl\frac{v^2}{2g}v=\frac{\delta a v}{2g}(v^2-v'^2) \quad (12)$$

where f is the coefficient of fluid friction, d the diameter of the narrow part, g the passage, and l its length. Observing that av = the volume per second $=\dfrac{\pi d^2 v}{4}$, and constant for at least an infinitesimal length, we reduce the above to

$$2a\frac{v-v'}{v}=\pi dfl,$$

or $$l=\frac{d'-d}{f} \qquad (13)$$

The same result would have been obtained had the equations been worked out for an infinitesimal length and variable density, and then integrated.

The final result shows that the difference of diameter at the opposite ends of the flaring smaller part of the passage is independent of the total diameter.

The value of f is about 0.006. Now, making $d'-d=\frac{1}{100}$ of an inch, then $l=$ 1.67 inches. These are the figures according to which the shunt tip experimented with was made. The diameter of the mouth at the tip was 0.065 inches, and at the 1.67 inches distance from the tip the passage was 0.075 inches, where it quickly enlarged to ¼-inch, the size for 2½ inches: beyond which, for about 18 inches, it was about ⅝-inch, where the light rubber bag was attached for catching the shunted gas. This bag was made especially for the purpose, of very thin "dental rubber."

When collected, the gas was measured by running it through an aspirator. When thus measured its temperature should be noted.

On account of the passage-way in the shunt being formed as one of no resistance, the gas collected per second is regarded as having flown through the shunt mouth at the same rate that it did outside the mouth, or with the normal velocity of the gas at the well mouth.

QUANTITY OF GAS DISCHARGED.

The quantity of discharge should be estimated at some standard temperature at which the gas is supposed to stand as if retained collected in a gas-holder, say 60° Fahr. But while the gas is flowing, its temperature will almost always be much lower, on account of the expansion which accompanies the flow. For instance, in the shunt verifying experiment of the air issuing from the receiver at initial 17 lbs. apparent pressure, the density of the stream of air just outside the plane of the orifice was 0.0937, instead of 0.0749 of the surrounding air into which the receiver was discharged, and the volume av calculated by using the velocity $v=1083$ would require to be increased about 25 per cent. to obtain the volume of the discharged air on the supposition of being collected and retained in a gas-holder at atmospheric pressure, and temperature of 60° Fahr.

The temperature of the air in the same jet from the receiver was about 38° below zero Fahr., which low temperature is to account for the high density in the jet.

Taking V for the volume discharged per second, then

$$V=Av\frac{\tau_0}{\tau},$$

where A=area of the stream of gas being measured, as for instance, that at the gas well mouth, or of the well mouth itself, τ_0 the absolute temperature of the gas when stored, and τ that of the gas in the stream. But

$$\frac{\tau_0}{\tau}=\frac{273+t_0}{273+t}=1+\frac{t_0-t}{273+t}\text{ Cent.}^\circ$$

$$=1+\frac{t_0-t}{461+t}\text{ Fahr.}^\circ \qquad (15)$$

Hence

$$V=Av+Av\frac{t_0-t}{273+t}\text{ Cent.}^\circ$$

$$=Av+Av\frac{t_0-t}{461+t}\text{ Fahr.}^\circ \qquad (16)$$

The volume discharged per day of 24 hours for dimensions in feet will be

$$\text{Vol. per day}=86400\ V. \qquad (17)$$

THE ENCASED THERMOMETER; OR TEMPERATURE OF STREAM.

In the impact of the gas against the open end of a tube, it is just as true, from theoretical grounds, at least, that the temperature will be restored as well as the pressure. That is referring to the case of the air issuing from the receiver through the orifice, the pressure in the Pitot's tube by impact has been shown to be up just to that in the receiver. Consequently, the air was compressed back to its original conditions as to temperature and volume very nearly, since the time for acquiring heat by a particle in the act of passing out against the tube mouth could not much exceed the 50 thousandth part of a second. The same is true of the density.

About a dozen experiments were made to test the question as to restoration of temperature in the cup mouth by means of an encased thermometer arrangement shown in Fig. 6. A glass tube, BC,

about $\frac{3}{4}$ inch diameter was drawn down at A to about $\frac{1}{4}$ inch diameter, for the mouth to present to the $\frac{1}{4}$ orifice, O, in the Westinghouse apparatus. Inside of AC is shown the encased thermometer supported in the center of the tube, and with its bulb, B, as near as practicable to A. In the plug at C is a small hole to allow a current to flow past the thermometer, so that the air in AC will not have time to be modified in temperature after being compressed at A, before it surrounds the thermometer bulb at B for determination of temperature.

There was no thermometer in the receiver to show its temperature. In experimenting, the pressure would fall, in each experiment, from between 30 and 40 lbs. per square inch to about 8 or 10, owing to which, the temperature would, of course, fall in the receiver. But at the same time, air was being pumped in as fast as the pump would work. Under these conditions, it is difficult to tell what the temperature in the receiver at any time was, but as the room was at about 25° C., it is probable that the interior of the receiver ranged from 15° to 20° C.

Exposing the naked thermometer bulb to the jet, while pressure fell from 35 to 10 lbs., the mercury fell to from 3 to 6 degrees below zero C.; but the real temperature of the jet must have been very much lower, from the fact that ice would form on the bulb and not melt nor even become moist for several minutes after removal of thermometer from jet and exposure to the air of the room, thus proving a great fall of temperature in the act of expansion at the orifice O. The actual temperature of jet could not be expected to be indicated by a naked thermometer in this way, for the reason that the impact of air upon the thermometer bulb, and friction of the flowing air passing it, would give such a tendency to elevation of temperature as to utterly defeat the effort to determine definite knowledge as to the actual temperature of the jet by means of a naked thermometer.

But in presenting the mouth of the *encased* thermometer to the jet, the mercury would stand very nearly steady at about 16° to 22° C., sometimes not falling a single degree. As this temperature was not far from that within the receiver, together with the fact that the naked thermometer would fall from 20° to 25° lower and yet not reach the limit, it appears that the encased thermometer is to be relied upon for indicating the temperature in the receiver.

Hence, from all the facts of experiment, and considerations above noted, we are prepared to state the following more general principle; for nonviscous, elastic or nonelastic fluids, viz.:

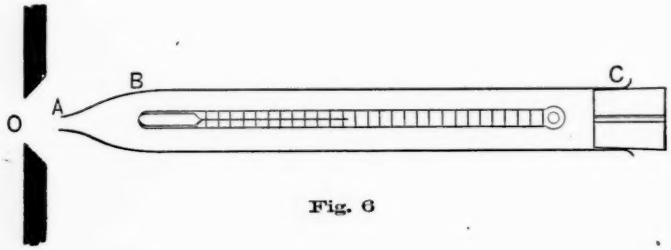


Fig. 6

When any fluid flows from a higher to lower pressure through a frictionless passage, the portion caught direct in a cup mouth will be restored to its original conditions as to pressure, temperature and density.

By using a tube of some nonconducting material, like pasteboard, or *papier maché*, for the casing Fig. 6, extending from A to some distance past the thermometer bulb, and then glass, better results would doubtless be obtained than for all glass, though glass would be much better than metal.

The temperature of the encased thermometer, as well as the pressure by the Pitot tube, for any stream of gas observed, should be regarded as that of the *equivalent receiver*, that is, a receiver from which the same gas would flow to

produce the same jet as that observed for which the temperature and pressure would be that of the encased thermometer and Pitot tube.

This fact is to be taken advantage of for securing the temperature of the flowing jet by calculation from the temperature as observed from a thermometer placed in the non-conductor tube.

Then the temperature of the stream of gas can be calculated from the well-known relation for adiabatic expansion,

$$\left(\frac{p_1}{p_2}\right)^{\frac{\gamma-1}{\gamma}}=1+m^2=\frac{\tau_1}{\tau}=1+\frac{t_1-t}{273+t}\text{ Cent.}^\circ$$

whence

$$t=\frac{t_1-273m^2}{1+m^2}\text{ Cent.}^\circ=\frac{t_1-461m^2}{1+m^2}\text{ Fahr.}^\circ$$

where t_1 is the temperature observed from the encased thermometer, m the value found from the table given above, and t the temperature of the stream. When the result for t comes out negative, it is to be read "below zero."

This value of t is to be used in (5), (7) or (10).

DENSITY, OR SPECIFIC GRAVITY.

As the formulas for calculating the velocity of flow contain the specific gravity of the gas, some convenient way of finding it is desirable. Where the analysis of the gas in question is not known, Bunsen's Effusion Principle, as already stated, may be applied. A simple way of doing this is to draw a $\frac{3}{8}$-inch glass tube down blunt to a fine orifice, put this into a cork, orifice up, and the cork into a bottle with the bottom knocked out. Then fill the bottle with water set it into a common plate filled with water. Now, let the water flow out over the edge of the plate and draw air in through the effusion orifice at the top of the tube in the cork and note the time. Then fill the bottle again, and similarly allow the gas in question to flow through the effusion orifice and empty the bottle, noting the time of flow. Then Bunsen's principle makes the densities proportional to the squares of the times, and the specific gravity equal to the ratio of the squares of the times.

A mark may be placed on the neck and near the bottom of the bottle to start and stop at; and a piece of rubber hose may be stuck upon the effusion tube and gripped to prevent flow till ready.

The gas may be caught from the gas well by a shunt in a light bag for the effusion tube to draw from in observing for time of effusion of gas, care being taken to get all air from the connections.

APPLICATIONS.

Primarily in this investigation, the object was to measure gas wells, but the appliances are applicable to other streams or currents of gas, even where the fluid is of indefinite extent, as in high winds. Several instances are known of failures of wind anemometers at the critical time of a most valuable record, because of delicacy, complexity, etc., of instrument. In the Pitot tube, we find an instrument of the greatest possible simplicity and stability, one not having a single moving part exposed to the wind.

Thus, to find a reliable wind velocity or pressure of the tornado, put up on strong iron frame-work, several Pitot tube points radiating in different directions, including up and down, each with double mouth, one direct and one lateral, connected properly with a gauge as above explained, with a maximum indicator. This contrivance could be left to stand by itself year after year, observed or not. Finally, the maximum wind pressure with direction could be read off. These could be located at various points about the country, any one of which struck by a cyclone, could make known the various interesting facts so much desired, as to pressure, velocity, variety of direction, lifting power, etc.

A double mouth tube placed inside a conducting pipe would show by gauge located at any convenient situation, the velocity in the pipe.

GAS WELLS.

The following results of application to gas wells can be given:

Karg Well, Findlay, Ohio.

At well mouth, Pitot tube pressure, 15 lbs. per square inch.

$$\frac{p_1}{p_2}=\frac{29.6}{14.6}=1.592$$

$m=0.4876$

$v=1513$ ft. per sec.

A=.0873 square ft.

Cubic ft. per day=12,080,000.

Cory Well, Findlay, Ohio.

End of 2″ pipe, 21 ft. from well mouth.

Pitot tube pressure, 9.25 lbs.

$$\frac{p_1}{p_2}=\frac{23.25}{14.6}=2.028.$$

$m=0.3797$

$v=1178$ ft. per sec.

A=.0308 square ft.

Cubic ft. per day=3,318,000.

By shunt at this well, the velocity was 1111. feet per second, by three observations giving 48.3, 45.2 and 44.6 cubic inches per second, respectively.

Briggs Well, Findlay, Ohio.

April 17th, 1886.

End of 2″ pipe, 91 ft. from well mouth.

Pitot tube pressure=6.5 lbs.

$$\frac{p_1}{p_2}=\frac{21.1}{14.6}=1.445$$

$m=.3274$

$v=1016$ feet per second.

A=.0276 square feet.

Cubic ft. per day=2,565,000

From a second stratum above the first, water gauge,

h. Inches.	Diameter. Inches.	Velocity. Feet.	Cubic feet per day.
0.48	$2\frac{3}{4}$	57.7	206,100
0.5625	$2\frac{1}{2}$	62.61	184,400
20.0	$1\frac{5}{16}$	449.5	186,200
		By Anemometer.....	186,400

These four measurements are for the same stream of gas.

Jones Well, Findlay, Ohio.

April 17th, 1886.

Pressure by water gauge,

h. Inches.	Diameter. Inches.	Velocity. Feet.	Cubic feet per day.
0.3125	$7\frac{1}{16}$	46.45	1,444,000
3.79	$3\frac{3}{8}$	161.7	918,600
		Mean.....	1,181,300
		By Anemometer.....	1,159,200

The jet was here very irregular, the gas being forced out at right angles through a valve, from the main well tubing; the first result being got from the end of a flaring funnel, and the second from the valve mouth direct. The several anemometer results also differed greatly among themselves.

STEEL SLEEPERS FOR PERMANENT WAY.

By J. W. POST.

Translated from Schweizerischer Bauzeitung, for Abstracts of the Institution of Civil Engineers.

From a railway point of view the introduction of steel sleepers is good, because the average life of a sleeper is increased, the price of wood sleepers is lowered by the competition, and in industrial countries the making of a ton of steel sleepers brings over the railways a traffic of about ten tons of raw material.

The first trials of hard steel-sleepers were not encouraging, and some railway companies gave them up at once. Other companies laid test lengths on different systems, inspected them carefully and kept statistics of the cost of maintenance. Especially was this done on the Dutch and German railways, and with some success, and to these trials are due the results and experience now available.

Since the Bessemer, Thomas and Siemens processes have rivaled each other in producing mild steel, steel sleepers have come much more into competition.

It is generally agreed that:

1. The average life of good steel sleepers is considerably longer than that of the best wooden ones.

2. The width of gauge is better maintained with steel sleepers.

3. The cost of maintenance of permanent way on steel sleepers remains almost constant after the second year, but on wood sleepers increases constantly with age, so that the average cost of the latter is greater.

4. There are systems of fastenings on steel sleepers which are at once safer and

more easily maintained than those for wood sleepers.

5. A good steel sleeper should not cost more than from 125 to 150 per cent. of the cost of a wood sleeper.

6. The "old material" value of a steel sleeper is greater than that of a wood sleeper.

If, for comparison of the relative cost per mile of steel and wood, account is taken of the manufacture, transport, laying, maintenance, interest (lately the low rate of interest has told in favor of the lasting material), and value as scrap, it is seen that there are few countries in the world where the exclusive use of wood sleepers is really economical. For countries where climate and insects destroy wood sleepers in a few years, this is evident; but it speaks better for steel sleepers that in Holland, which produces no steel and gets wood sleepers very cheaply by sea, all the railway companies have introduced metal sleepers without any pressure from the Government

The first metal sleepers were too weak; owing to a mistaken idea that they must be as cheap as those of wood, they were made only from 55 to 66 lbs. weight, and it was not clearly seen that they were weakest where the rails rested on them, because (1) the holes of the fastening reduce the cross section; (2) the punching of the holes makes the metal round them more or less brittle; (3) the foot of the rail and the fastenings eat in time into the top of the sleeper; (4) with rational beating up of the ballast the moment of reaction of the ballast is a maximum at the cross-section where the wheel load is applied; (5) the impulse of the moving is transferred directly to the sleepers at these places; and (6) in the various systems the material suffers most at these places during the forming of the 1 in 20 slope, to give the cant to the rail, whether that is done in the hot or cold.

The disadvantages of the sleepers being too weak soon showed, in the bending and shaking, the escape of the ballast and consequent expensive maintenance; also in the cracking of the sleepers lengthwise and crosswise where the rails rest. Some railways then introduced heavier sleepers (up to 165 lbs. weight), which lasted well, but were expensive. Various attempts to strengthen the sleeper by riveting or bolting to it plates for the rail to rest on, with or without the 1 in 20 slope, were unsuccessful because of the increased cost, or because the connection between rail and sleeper was less secure.

Latterly improvements in rolling machinery have rendered it possible to make sleepers of varying thickness, and having the 1 in 20 slope for the rail, the whole being done in the process of rolling. This improvement enables the metal to be disposed where most required, and effects a saving in weight of from 12 to 21 per cent. in the sleeper. The minimum cross-section of the sleeper is kept for about two-thirds of the length, while it is thickened under the rail and for a short distance on each side of it.

After the Netherlands State Railway Company had for some years laid test lengths of their main line on sharp curves and heavy gradients, with iron and steel sleepers of various designs, and carefully compared the cost of maintenance with that of similar lengths of line laid on new oak sleepers, they decided in favor of the mild steel sleepers, 8 feet 6 inches long, 9.25 inches wide over the extreme edges at the bottom, 2.52 inches deep for the greater part of its length but increased to 2.92 inches under the rail, and 3.23 inches at about 4 inches outside the rail, so as to give the inclination of 1 in 20 for the cant of the flat-bottomed rail which rests directly on the sleeper. Advantage was taken of the low prices of steel during the past two years to lay down large quantities of these sleepers on the Dutch, Belgian and German lines of the company. One of the district engineers in his annual report for 1884, states that on a test piece of line 1,144 yards long, on a curve of 820 yards radius and a gradient of 1 in 83, no beating up of the sleepers was required for twenty-two months ending December 31, 1884, and that the only maintenance required was one man for thirty-four days inspecting and tightening up the bolts. He states that the cost of maintenance of a steel sleeper road, three and a-half years old, is the same as that of the same age laid on wooden sleepers, but that from this point the cost of the latter increases, while the cost of the former tends to diminish, owing to the consolidation of the bed. The following advantages are claimed for the sleeper

(adopted from the St. Gothard Railway) by the Netherlands State Railway Company:

1. It is easily packed with any kind of ballast, sand, gravel, ashes or slag.

2. The triangular toe which forms the bottom edge of the sloping sides of the sleeper prevents damage to the edge during beating up, and by lowering the neutral axis of the section gives additional stiffness. It also makes the section easier to roll.

3. It gives a broad surface to the foot of the rail to rest upon.

The weight of this sleeper is 104.7 lbs., whereas a sleeper of the same strength, with a uniform instead of a varying cross-section, would weigh 15 per cent. more. The last steel sleepers ordered (July, 1885) cost at the works, including a two years' guarantee, not quite 6 francs each, or almost the same as an oak sleeper.

The author proceeds to show by drawings how by giving them a varying cross-section the various forms of steel sleepers now in use may be improved, including the Vautherin, Elberfeld, Prussian State Railways, Rhenish Railway and Austrian Railway patterns. The principle is applicable not only to sleepers for Vignoles rails, but the advantage of the local strengthening is even more apparent when, as in the case of Webb's sleepers as used on the London and North-Western Railway, a number of holes have to be made in the sleeper for the attachment of a chair to carry a bull-head rail; for in order that the rivets may hold for a length of time it is necessary that the plates should have a certain thickness.

There has been much discussion as to the relative merits of the Vignoles and bull-head rails, and German engineers who have been sent to England to report upon English permanent way, and its small cost of maintenance, have sometimes overlooked the fact that it weighs from 400 to 550 lbs. per yard as against 240 to 320 lbs. per yard, the weight of the German line. For the same price as is paid for the English permanent way a line on the German system could be made just as solid and capable of resistance.

It has been objected that metal sleepers are not heavy enough to make a good permanent way. The secret of a good sleeper is, however, not weight alone, but depends also on—

(1) Appropriate form.

(2) A section with sufficient moment of resistance.

(3) A material not easily fractured.

(4) Sufficient bearing area and length.

As to form, the closing of the end of the sleeper deserves special attention. In the early open-ended sleepers the 1 in 20 slope for the bed of the rail tended to drive the ballast out from underneath, while a sloping closed end, as now used by the Netherlands Railway Company, tends to drive the ballast in under the rail.

In order that the punching of the holes for fastenings may not have an injurious effect hard steel is now avoided, and the sleepers are made of mild steel (Bessemer, Thomas or Siemens) capable of resisting a tensile strain of 25.4 to 28.6 tons per square inch, with a minimum contraction of 30 to 40 per cent.

In case of anything leaving the line, also, mild steel is much to be preferred to hard steel for sleepers, as it is less liable to be broken.

Formerly there was anxiety as to the rusting of iron sleepers, but it is now known that this is trifling in the case of sleepers in use, so few railway companies use preventives such as galvanizing, steam oxidation, oxide of lead or tar. Only for the sleepers kept in reserve by the side of the line or for parts of the line where the atmospheric influences are bad (damp tunnels), or for sleepers for transport by sea is it needful to use tar or paint.

After many years of trial the Netherlands State Railway has decided to keep to screw-bolts as the means of attachment between the rail and sleeper. In 1865 they had lain ten thousand iron sleepers of a now antiquated design on their main line near Deventer. The rails were fastened by four bolts, 0.42 inch diameter, to each sleeper. For the first time, in 1883, it was necessary to renew two thousand of these forty thousand bolts, and the remaining thirty-eight thousand are still (August, 1885) in use. This shows the bolts 0.86 inch in diameter now used will be satisfactory. The bolt-holes in the sleepers are square except that the corners are slightly rounded.

The beating up of the ballast under steel sleepers must be so done that the middle of the sleeper is filled but not with compact ballast, while for a distance of 12 to 15 inches on each side of the rail the ballast must be well beaten up.

It is also very important that during the first few months after the sleepers are laid, the road should have great and constant attention until the beds become consolidated. The cost of this ought to be considered as part of the cost of laying the road.

FLOODING THE SAHARA.

By GEO. W. PLYMPTON.

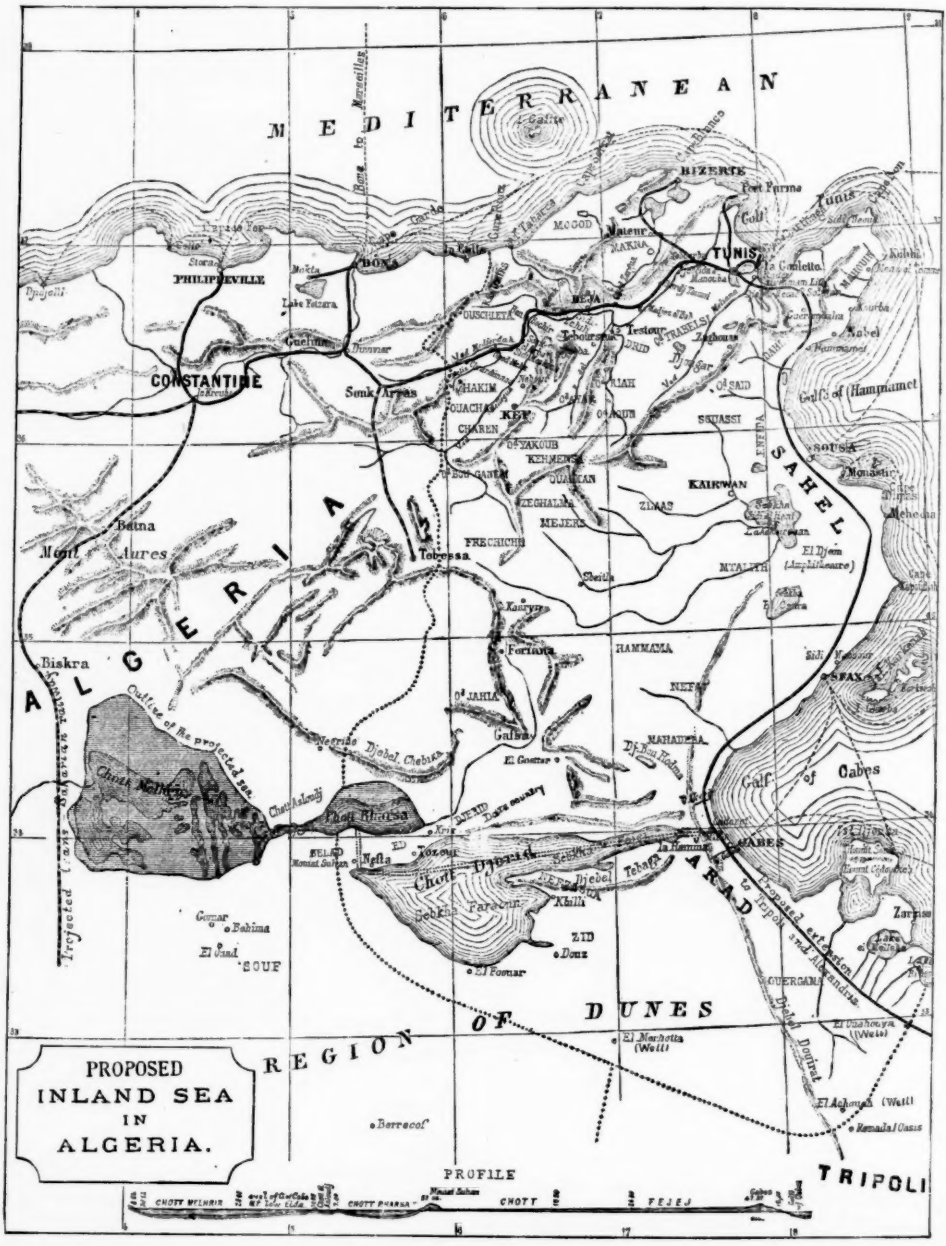
From "Science."

Much misinformation has of late been spread abroad respecting "the proposed interior sea of Africa," and the public has been misled by inaccurate statements in regard to the magnitude of the enterprise, which, it is assumed, the French people are about to undertake. For these current erroneous impressions the English and American scientific journals are largely to blame. An old theory regarding the Sahara—that it was for the most part below the level of the ocean—has been adopted as though modern surveys had not refuted it; and so the conversion of a material portion of the African continent into a navigable sea is being popularly considered as not only possible, but altogether likely to be accomplished.

A brief consideration of the published results of the recent surveys will be sufficient to convince the reader that the popular estimate of the magnitude of this enterprise is absurdly out of proportion to the greatest possible accomplishment.

This overestimate is not surprising when we consider the character of the references to the scheme which have been made by journals of the best standing. The following paragraph from the foremost among engineering journals may be taken as a sample:

"With reference to the daring French project for flooding the desert of Sahara with what would be virtually a new sea, it may be well to recall the opinion expressed by M. Elisée Réclus, that at one period in the world's history the desert was covered by a sea very similar to the Mediterranean, and that this sea exercised a very great influence upon the temperature of France, as comparatively cold—or, at any rate, cool—winds blew over it, while now the winds which prevail in the great expanse are of a much higher temperature, and are, in fact, sometimes suffocatingly hot. The appearance of the desert seems to support the theory of M. Elisée Réclus, that it was at one time the bed of a sea of considerable extent, of which the great inland African lakes recently discovered are possibly the remains. The present vast extent and configuration of the African continent would also appear to support the conclusion that at one time it comprised a less area of land than it does at present. The serious question which arises, assuming that the theory of M. Elisée Réclus is substantially correct, is, What will be the effect of the creation of a second African sea in the room of that which has disappeared? Would the temperature of France, and possibly even of England, be again reduced? It is a geological theory that in the glacial period of the world's history Great Britain was covered with ice and snow very much as Greenland is at present. Some great influences must clearly have been brought to bear upon France and Great Britain, which rolled the ice over so many hundred miles northward. What was this influence? Was it the large African sea which French enterprise is endeavoring to recreate? If it were, we should say that whatever the French may gain in Africa by the realization of a Saharan Sea would be much more than counterbalanced by what they would lose in France itself."



PROPOSED INLAND SEA IN ALGERIA.

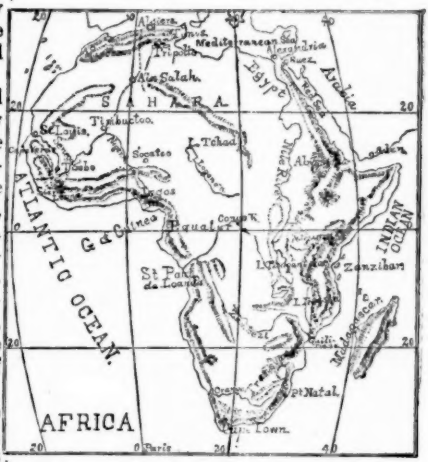
A writer in another journal suggests that all nations interested in the commerce of the Mediterranean may by right protest against the execution of a scheme that would produce a troublesome current through the Straits of Gibraltar. And the same writer, furthermore, adds, "So much water drawn from the present oceans, may, by lessening the depths of the harbors of the world, produce serious and wide-spread inconvenience."

That all such fears are utterly groundless is abundantly shown by the results of the careful surveys made within the last few years. A brief résumé of these results is presented below. The figures are reduced from the metric measures in "Nouvelle geographie universelle," by Réclus, and the maps from "Le génie civil." In both cases the authority quoted is the French engineer, M. Roudaire.

Every one who, as a student, has had to draw the map of Africa, can certainly recall that singular interruption to the otherwise regular coast-line on the extreme northern boundary, where the coast, for a comparatively short distance, has a general north and south trend. This notch marks the north-eastern terminus of the Atlas mountain system. The eastern shore is the eastern boundary of Tunis; and on it, in ancient times, stood Carthage. An indentation at the southern part is called the Gulf of Gabès.

A line extending due west from the shore of this gulf crosses a barren region, of no interest but for the project about which this article is written. It is a region abounding in basin-shaped depressions, containing either shallow salt-marshes, brackish pools, or deposits of salt and gypsum. The more extensive areas are called "chotts." The first of these is the Chott-el-Fedjedj, the eastern end of which is 12 miles from the shore of the gulf, and separated from it by a ridge of drift and limestone whose altitude at the lowest point is 150 feet. The surface of el-Fedjedj is nowhere less than 48 feet above the sea. Toward the west it is contracted in width somewhat by the encroachment of the ridges which bound it on the north and south. Beyond this point, which is about 70 miles from its eastern limit, it widens out, and is known as Chott-el-Djerid. Here the surface is for the most part level, and covered with an incrustation of salt, beneath which, in a few places, are pools of water. The plain of el-Djerid is from 50 to 200 feet above the sea-level. Its width from north to south is about 45 miles.

Near the north-west border of el-Djerid, and separated from it by a ridge whose least altitude is 550 feet, is the Chott Gharsa or Rharsa, whose surface is from 30 to 35 feet below the level of the sea. Gharsa is about 50 miles long and 20 miles wide. Beyond this chott to the west, and separated from it by an insignificant elevation, is a much larger depressed area, known as Chott Melghigh or Melhrie. This is the basin referred



MAP OF AFRICA, SHOWING THE RELATIVE SIZE OF THE PROPOSED INLAND SEAS.

to as the site of the proposed interior sea. The area which, lying below the Mediterranean, can possibly be flooded by it, is represented by the shaded portion on the accompanying maps.* Portions of this area are 100 feet below the sea-level; and the average depth, if flooded, would be 78 feet.

The figures above given exhibit the possible dimensions of the "flooded Sahara." The united areas of the two chotts over which the sea would flow is, by Roudaire's measurements, about 3,100 square miles, less than half the area of Lake Ontario.

* The scale of the larger map is about 58 miles to the inch.

Throughout the remainder of the Great Desert the elevation is considerable. Competent authorities estimate the average height at 1,100 feet. Dr. Lenz found, in traveling over many hundred miles of the western portion of the Sahara, no point of less altitude than 470 feet above the sea.

The fact that marine deposits are found in many parts of this area is, of course, a fact of no significance in this connection. The skeleton of a whale found in one of the highest cuttings of the Vermont Central Railway is not regarded as an evidence that the Green Mountains could now be submerged by the waters of the ocean.

The whale probably stranded there during what geologists term the "Champlain epoch," since which time the surface has slowly risen. The hypothesis that at least eighty thousand years have elapsed since this epoch is believed by most geologists to be well founded. Explorations across the African desert justify the belief that the marine deposits found there are not less ancient than those of the Champlain period.

To flood such a section with the sea, either the next great subsidence must be patiently awaited, or else an extensive system of pumping must be resorted to. The realization of the scheme of submergence (to accord with the popular estimate of it), by either of these plans, may be regarded as equally remote.

The project of flooding the Sahara to the utmost practicable limit can hardly be called a great one. It is safe to say, that if executed, which is doubtful, it will not sensibly affect the climate of southern Europe. It will not create dangerous currents at Gibraltar, nor inconvenience seaports in any part of the world.

ELIMINATION OF ERRORS IN FIELD WORK.

By WM. BOUTON, Member of the Engineers' Club of St. Louis.

Journal of the Association of Engineering Societies.

Accuracy is a relative term. "We speak of a thing as accurate with reference to the care bestowed upon its execution, and the increased correctness to be expected therefrom" (Webster's Synonyms). It would not be accuracy but confiscation to expend the same amount of painstaking labor in surveying land worth one dollar and a quarter an acre that would be essential in surveying town lots, where the walls of valuable buildings abut with precision upon the property lines. The purpose of the work determines the method which should be used, and the amount of human frailty which may receive the award "well done." Old surveys are often retraced by the methods originally used, and are found accurate, *i.e.*, without mistake, and with a care adequate to the use for which the property is fitted. When the use changes, and with it the method of surveying, it is probable that every line will have a revised and corrected length, every angle a different observed value. A surveyor engaged in such work is trying to find out how much the ground has grown since it was measured last. Mr. Culley (see the *Journal* of September, 1884), makes an earnest appeal for the transit and steel tape for farm surveying. When the course of the survey strikes into ground that is covered with briars and hazel brush, honey locust and poison oak, grape vines and other vines too numerous to mention, with weeds ten feet high wherever they can get breathing room, I confess that for my part I prefer the compass and chain, and consider that method entirely adequate until the land can be put to some better use; but if the land is well cultivated and the fence rows are clean, it is practicable to use the transit and tape without much extra cost and with very much more satisfactory results. It is generally true that the earliest application of more accurate methods finds, before the work can proceed, more rough places to be made smooth, than crooked places to be made straight. The best work cannot be done under such circumstances; while human nature

stops short of absolute perfection, the quality of the work, of those who are competent and careful, will be affected by conditions under which their work is done. To him who makes the elimination of error from his own work a labor of love, or a matter of professional pride, it will soon be plain that every kind of error, which can in the nature of the case possibly exist, will some time be found, that the simplest kinds of work involve many possibilities of error, and will further find that every check introduced into the work in order to prevent error, brings in its train new possibilities of error.

If the problem is to retrace an old survey, having the original notes, a comparison of the resurvey with the original will probably show errors in one or the other, which may be classified as follows:

1. Errors due to difference of method used.

2. Errors due to the extent of the work and to the passage of obstacles.

3. Errors in the work or record due to the incompetence or carelessness of either surveyor.

These observed errors are the algebraic difference of errors, kind for kind, of the two surveys. The true values are not to be reached by a division of the observed errors, nor by the assumption that they all belong to the older survey. Approximation to the truth is to be sought for in the increased care given to resurveys.

When a survey takes the form of a subdivision with a recorded plat, and deeds are made referring to the plat of record, the number of possible errors is very much increased. In making a subdivision no pains should be spared (here virtue brings its own reward, if not to the surveyor, at least to the community); the plat should be mathematically consistent, and should correctly show how the subdivision stands related to original property lines; monuments marking the more important points of subdivision should be accurately placed upon the ground. Angles as well as lines and distances are an essential part of a workmanlike plat. The ideal subdivision is seldom seen. On the other hand, the number of hairs in a man's head would all be needed, if he should attempt to keep tally with them in how many ways a subdivision, or its recorded plat, or the corner stones may be wrong.

Next comes the conveyancing built upon this foundation. An ingenious notary can make things lively for a surveyor; the ha'f was never told.

The field notes purport to give an account of how the corners have been perpetuated, what marks now exist and how the subdivision has been verified by resurvey. If they fail to give this information, that failure is often a source of error.

The place where most of the errors so far noted should be corrected is in the office, but the place where they will materialize, if not corrected, is in the field. They form the vast majority of the reasons why "two surveyors can never agree." A judiciously arranged and thoroughly equipped office is an essential precedent to correct field work, and makes many things possible which, without it, are impossible.

There are surveyors who say, "I don't go into any such questions. I survey what is ordered. If a man brings his deed to me, and says, 'I want this lot surveyed,' and that deed contains a description which can be located, I follow it; if it contains other words and phrases which presumably mean something, but what they mean is uncertain, I ignore them—all that belongs to the investigator of titles."

Suppose that this statement is made to the owner of the lot, and he says, "Yes; I had the title investigated, here is my abstract." You take it, and read the description in the deed, possibly with the puzzling phrases omitted, and a certificate like this: "I have examined the public records of X county, and the indexes thereto attached, and find the title to the above-described lot fully vested in John Smith; taxes paid; judgments, none," you don't feel that you have learned much; but if you inquire further, the investigator will tell you something like this: "The *chain of title* is complete from the original owner to the present. The conveyances are in due form." "But," you ask, "what is the force of this call for boundary?" or this: "And being the same property conveyed by deed of Brown to Jones?" He may reply, "The wording of that deed from Brown was a little different from that of the present deed; but it is not such a difference that

I can sit here in my office, and, looking at the two papers, say that they must mean different things; that is a *question for surveyors.* As to that 'boundary,' I was investigating Smith's title, not his neighbor's." Between such investigators and such surveyors and notaries, who are willing to add or omit a word or phrase in order to make the meaning as they understand it plain, there is many a stitch dropped. Neither can keep closely to what he is pleased to term his own business and give a final result free from mistakes. If there be a mistake in some such way caused, whose fault is it that the location is wrong? Generally, I think, the surveyor's. He is employed to correctly interpret the meaning of that deed by marks upon the ground. It is his business to get, and require pay for getting, in some way the information necessary in order to do the work. Interpretation presupposes understanding; it will not do, while a part of the deed is in doubt, to interpret what is plain and say, "This is all." Some State law-makers need to learn this lesson.

"If the work so far described has been well done, the field work is next in order. The location of a line is the accurate determination and marking of its origin, direction and length. There is a trite saying, "If surveyors could only agree on what they should measure from, the rest of the differences would be of little account." While there is something to be said as to other differences, after this branch of the subject is finished, I feel compelled to admit that there is a deal of force in this view. It involves the perpetuation of lines by all the methods known to the craft, and the verification to-day of that which survives from the past. In a majority of instances in this city the deeds recite that the property sold is a part of —— Subdivision, as per plat of record. The recorded plat usually does not show how the lines were marked; does not even show that they were ever marked at all. Nevertheless it is fairly probable that stones or other monuments have been set. What is now the proper thing to do? Shall I agree with Pope that, "whatever is, is right," and take unquestioning that which first comes to hand and make from it the required location? If so, my neighbor who has an office across the street, may with equal right measure from the other end of the block and certify my survey wrong. Monuments derive their authority, not from the fact that they exist, but from the fact that they conform with reasonable accuracy to the recorded plat. To say that the location of the subdivision logically precedes the location of lots within it, is but another way of saying the same thing. It is the surveyor's business, not to assume, but to know with reasonable, or at least with all attainable certainty, that the monuments found correspond to the subdivision. Having once verified carefully the position of corner stones, or whatever else approximates permanence, that position is for the future a matter of knowledge. But the *permanence* of all marks whose position is essential to the survey must whenever used be tested before a location is made.

Although much field work has been implied in what has been already said, the discussion of methods of measuring has been left until more important things were disposed of; no care in determining the length of a line can make that survey correct which begins in the wrong place and ends nowhere.

Considered as affecting the result, errors are plus or minus. Some of the sources of error which affect every piece of work are as likely to produce plus as minus errors, and will, in fact, produce both plus and minus errors in the same piece of work, *e. g.*, inaccuracies in observing the point of a plumb, or its vibration in a still day. The theory of probability shows that if the number of trials is made sufficiently large the number of times when each possible event will occur will be in precise proportion to the probability of that event. If the errors due to any source are as likely to be plus as minus, the relative resultant error will become less than any assignable limit, as the extent of the work approximates infinity. Experience will enable the surveyor to fix upon the value of the maximum error in his own work for a short distance, say 100 feet. The maximum possible error is a simple multiple of this, and it is something approximating this maximum occurring at improbable and unexpected times that plagues and costs reputation at least. I have found no better way of eliminating this possibility

than by measuring and running general lines, such as boundaries of the larger tracts, then cutting up the area by intersecting lines and tying up every survey at both ends.

Other sources of error are in their nature not compensating but cumulative. The ideal surveyor applies such a correction as to make every cumulative error compensating. In the free-hand work of the surveyor, any cumulative error, if platted in terms of the distance measured, would show a wavy line; a correction of its average value would leave a compensating error—a sort of second differential. I proceed to consider some cases.

Within the last twenty years the old method of using wooden rods when accurate measurement was desired has been with great advantage replaced by the use of the steel tape. The surveyor professes to give the horizontal distances between points noted. A man measuring with a tape never measures a horizontal distance. What he does measure is a succession of catenary curves. Men who ought to know better have suggested that this may be all very true, but it don't amount to much anyhow. I suggest the following as worthy of notice. Any curve is longer than its chord; it is also longer than the sum of the two chords which join its ends with its middle point. If the tape used is fifty feet long, and the sag at the center is one-half a foot, the short chords diverge from the long chords at the rate of two feet in one hundred. A moment's inspection of a table of cosines will show that the sum of the short chords exceeds that of the long chords by more than one foot in a mile. I consider that this approximate error from one source is greater than the sum of all the errors which a reasonable man surveying city lots should admit into his work. The case demands attention.

The following table I have found convenient in my own work, and submit for what it is worth. Taking the condition that the tape is of uniform section and carries no load except its own weight, I use the following nomenclature:

H = horizontal tension.
w = weight of unit of length.
W = weight of tape.
e = base of Naperian logarithms.
s = length of curve from origin.
l = length of tape.
x and y = horizontal and vertical co-ordinates, origin at lowest point.

Then $y=\frac{H}{2w}\left(e^{\frac{wx}{H}}+e^{-\frac{wx}{H}}-2\right)$,

and $S=\frac{H}{2w}\left(e^{\frac{wx}{H}}-e^{-\frac{wx}{H}}\right)$.

Observe that if $\frac{H}{2w}$ is constant, y and s constant, for $x=\frac{1}{2}l$.

For assumed values of this ratio varying between sufficiently wide limits, the effects of the sag and of the corresponding pull are tabulated. When the sag is

x=25 Feet. Tape 50 Feet Long.

Sag.			Pull.		Resultant ±.			
					Error in 50 Feet.		Error in 1,000 Feet.	
$\frac{H}{w}$.	y.	Excess of Curve. −Error.	$\frac{H}{W}$	Elongat'n +Error.	−	+	−	+
	Feet.	Feet.		Feet.	Feet.	Feet.	Feet.	
400	0.78	0 0326	8	0.0025	0.0301	—	0.602	—
500	0.63	0.0200	10	0.0031	0.0169	—	0.338	—
600	0.52	0.0140	12	0.0037	0.0103	—	0.206	—
700	0.45	0.0098	14	0.0043	0.0055	—	0.110	—
800	0.39	0.0071	16	0.0050	0.0021	—	0.042	—
900	0.35	0.0055	18	0.0056	—	0.0001	—	0.002
1,000	0.31	0.0045	20	0.0062	—	0.0017	—	0.034
1,100	0.28	0.0040	22	0.0068	—	0.0028	—	0.056
1,200	0.26	0.0037	24	0.0075	—	0.0038	—	0.076
							—	

x=50 Feet. Tape 100 Feet Long.

Sag.			Pull.		Resultant ±.			
					Error in 100 Feet.		Error in 1,000 Feet.	
$\frac{H}{w}$	y.	Excess of Curve. −Error.	$\frac{H}{W}$	Elongat'n +Error.	−	+	−	+
	Feet.	Feet.		Feet.	Feet.	Feet.	Feet.	Feet.
800	1.56	0.0652	8	0.0099	0.0553	—	0.553	—
900	1.39	0.0509	9	0.0112	0.0397	—	0.397	—
1,000	1.25	0.0400	10	0.0124	0.0276	—	0.276	—
1,100	1.14	0.0334	11	0.0137	0.0197	—	0.197	—
1,200	1.04	0.0279	12	0.0149	0.0130	—	0.130	—
1,300	0.96	0.0234	13	0.0161	0.0073	—	0.073	—
1,400	0.89	0.0196	14	0.0174	0.0022	—	0.022	—
1,500	0.83	0 0166	15	0.0186	—	0.0020	—	0.020
1,600	0.78	0.0142	16	0 0199	—	0 0057	—	0.057
1,800	0.70	0.0109	18	0.0223	—	0.0114	—	0.114
2,000	0 62	0.0090	20	0.0249	—	0.0159	—	0.159
2,400	0.52	0.0074	24	0.0298	—	0.0224	—	0.224

observed the errors shown are correct, the pull need not be observed, and the tape may be heavy or light. If an engineer prefers to estimate or measure his pull rather than his sag, let him divide his pull by the weight of his tape and seek the quotient in the fourth column and the corresponding error in the sixth or seventh. I add the second part of the table for such as prefer a tape 100 feet long.

In the formula elongation $= \frac{P\,l}{E\,k'}\,\frac{P}{k}$ is a multiple of $\frac{H}{w}$ in the first column of the table. Hence the elongation varies as $\frac{H}{w}$. I have used $w=3.4\,k$ for tempered steel. A change in E, modulus of elasticity, would change the fifth column and all derived from it.

I do not think there can be a difference in tempered steel reduced to so small a section as a tape which will be of sufficient importance to be taken account of in surveyors' work. Professor Johnson, of our club, made, in 1881, for the United States, a series of experiments upon a Chesterman 300 feet long; he found E=27,400,000. I have used his coefficient. I see Mr. Culley uses 29,000,000, but cannot find any reason to suppose it has better authority. It would appear from the table that it is practicable to pull such an amount that no correction need be applied for these errors. Experience will show, however, that, if the habitual pull is right for a perfect calm, the slightest wind will carry out the center of the tape to fully one-half a foot sag, without being sufficient to suggest the necessity for increasing the pull in order to reduce the sag.

A second reason why surveyors do not measure horizontal distances is that the ends of the tape are not kept level. If a man says "I can do it," watch him closely, for when he succeeds it will be a mistake. If he says "I can come pretty near it," give him credit for understanding the situation and watch him too. There is a difference of ability to judge, but at some point every person would recognize such an error. In this case we have the joint judgment of at least two men presumably somewhat experienced.

The limit of their error will be approximately uniform for like conditions; probably will not exceed two per cent. of the length of the tape. We may suppose that no error in judging the level exceeds two per cent., and assuming a probable distribution of errors within that limit calculate the probable correction, but the result is too small to account for the facts. A surveyor of any experience knows that somehow or other this correction must sometimes amount to con-

siderable. On lines where appearances are deceiving, it is customary, when there is a difference of opinion, to test the matter by plumbing a different height, and correcting the pin, if an error is apparent. Now this method of correction is not applicable to errors of inclination, which are smaller than two per cent., and some which are larger than that will slip through. On some lines this check is necessary every time for a large part of the distance. On such lines the head is no longer level; the apparent horizontal differs from the truth, and the probable range of error instead of being equally each side of the horizontal, is all one side, and may be at its limit nearly five per cent. The part exceeding two per cent. may be very nearly all eliminated by the method noted above. I conclude that there is *always* an error due to the fact that the tape is not horizontal, and this is always a minus error. A constant correction for it and for the resultant between sag and pull should be determined by the surveyor for his "team," and applied to sticking of the pin. A further minus correction is due this cause on difficult lines, before it should be called a mistake; at its extreme limit I place it at two-tenths of a foot in one thousand feet —the correction due to an inclination of two per cent. This further correction should never be applied to *graded* lines, for there such an error is inexcusable.

"Were it not for variations due to temperature," Mr. Culley says, "All lines, both long and short, within the scope of the land surveyor, could be measured exactly." The idea of dating a survey in order to be able to judge of the probable error due to this cause, which he suggests farther on, may do in Cleveland; but in a climate which boasts of 80° F. in January, and 60° F. in July, with a wide range of temperature in any month, this method of eliminating the error is fallacious. The plus and minus maximum errors due to this cause are very large; but the easiest in the whole list to manage. I attach a thermometer to my transit so as to carry it conveniently, observe the temperature in the sun or in the shade, according to the average condition of the line, and make the correction then and there.

The standards furnished by the Government are rods of steel correct at 60° F., or as marked. Using these, a rod of steel as long as the tape used should be marked with the standard length at 60° F. This standard, for obvious reasons, should be sheltered from the sun, wind and rain. If an office floor is long enough, it will furnish a convenient place for fixing it. The center should be held firmly, and the ends be so fastened that they may expand freely, but cannot be bent or sprung out of place. The marking should be done after it is in place. A tape tested on such a standard is correct at 60° F., whatever may be the temperature when the test takes place, provided that the tape be brought to the *same temperature* as the rod before the test is made. All measurements should be made with the tape at its tested length, and the correction applied to the whole distance measured. Some tapes are made so as to apply the correction to the tape. I have tried both ways, and don't want any adjustable tape in my work. A thermometer is equally necessary, and one more loose end is to be watched with no corresponding advantage.

I have found this table useful on a fly leaf of my field book:

—Errors.

Deg. F.	100′	200′	300′	400′	500′	600′	700′	800′	900′
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0	0.042	0.084	0.126	0.168	0.210	0.252	0.294	0.336	.378
10	.035	.070	.105	.140	.175	.210	.245	.280	.315
20	.028	.056	.084	.112	.140	.168	.196	.224	.252
30	.021	.042	.063	.084	.105	.126	.147	.168	.189
40	.014	.028	.042	.056	.070	.084	.098	.112	.126
50	.007	.014	.021	.028	.035	.042	.049	.056	.063

	+Errors.								
70	.007	.014	.021	.028	.035	.042	.049	.056	.063
80	.014	.028	.042	.056	.070	.084	.098	.112	.126
90	.021	.042	.063	.084	.105	.126	.147	.168	.189
100	.028	.056	.084	.112	.140	.168	.196	.224	.252
110	.035	.070	.105	.140	.175	.210	.245	.280	.315
120	.042	.084	.126	.168	.210	.252	.294	.336	.378

There is nothing new in it, but it is better to do a simple thing right once for all than to be doing it over and over again for all time.

The force of the wind upsets all these calculations. Our catenary curve that was a function of x and y is now a function of x, y and z. The plumb ceases to point to the center of the earth. Its average position is misleading—is the result of a composition of forces. These effects can be mitigated to some extent by holding the center of the tape to its place in line, by shielding the plumb and increasing the pull; but such work is always unsatisfactory. The only way to eliminate this source of manifold errors is to cease from any piece of work when the wind is so high that it cannot be done as it should be done. There are estimates, topography, etc., which do not require a high degree of precision and can be done when other work cannot.

Subdivision work, where it is proposed to to build brick walls to property lines, showing errors in closing or subdivision of 1 in 5,000, should doubtless be retraced. The average error of re-surveys, built on such a basis, need not exceed 1 in 20,000. The maximum error can then be kept within manageable limits.

SOME POINTS ABOUT MODERN WAR SHIPS

By LIEUT. B. A. FISKE, U.S.N.

The best rough measure of the value of a modern war ship is the weight of water she displaces, for this equals the weight of the ship and her contents, and the greater it is the larger her hull can be, the thicker her armor, the more powerful her engines, the heavier her guns, and the greater her coal and ammunition capacity.

A perfect war ship would be one able to resist any projectile or torpedo and to pierce any armor made, and at the same time to throw a greater weight of metal per minute, to turn more rapidly, and to steam faster and further than any other.

Ability to resist any projectile or torpedo would necessitate great thickness of armor and a heavy inner bottom; ability to pierce any armor would require very large guns; ability to throw a greater weight of metal per minute than any foreign war ship would render necessary a considerable number of guns, and these would require a considerable space to be protected, which means a considerable extent of armor.

We can see at a glance that the weight of guns and armor alone would be enormous, and that, in consequence, the ship would be immense, since she must be, not only as large as a volume of water of equal weight, but larger, in order that she may possess sufficient reserve buoyancy to float her when a sea comes on board, or when a water-tight compartment fills after a torpedo explosion or a collision. But the ship must be large enough to float, in addition, her machinery and coal, and these would be very heavy, since the boilers and engines must be very powerful in order to secure the necessary speed, and must have an enormous supply of coal at hand in order to steam the necessary distance.

Clearly, a perfect war ship would be an exceedingly heavy and expensive one. An English naval architect in a recent lecture before the Royal Naval College,

stated that a war ship, to be even approximately perfect, would weigh about 25,000 tons, and cost, at least, £2,000,000!

Since perfection cannot, at any practicable cost, be attained in any one war ship, the only thing to do is to design a number for different purposes, seeking in each certain excellencies, and resigning others. In a heavily armored ship, in which power of offence and defence must be very great, the weight allowed must be expended principally in guns and armor, so that great speed and coal endurance have to be abandoned. In a cruiser, on the other hand, speed and coal endurance are essential, so that armor and heavy guns must be resigned; while in a gunboat heavy guns and great speed must be secured, and armor and coal endurance sacrificed.

Furthermore, speed is comparatively an easy thing to get in a ship, if we are at liberty to make her as long, as narrow, and as deep as we please, and to place the boilers, engines and steam-pipes in convenient positions. But a long ship will not turn so quickly as a shorter one, yet handiness is almost as important in a war ship as speed; a long ship cannot have so thick armor as a shorter one carrying an equal weight of armor, and she is easier to hit. To make a war ship deep forces on her the naval disadvantage of great draught, which prevents her from entering some harbors and from chasing vessels near some coasts; and boilers, engines and steam-pipes have to be crowded below the water line to protect them from projectiles. Is it a matter for wonder, then, that war ships are not so fast as some passenger steamers whose requirements are so simple?

It is sometimes urged that war ships should carry a great deal of sail, in order to be able to stay a long time at sea without going into port for coal. But masts and spars are very heavy; they fall on deck when struck in action, and kill men, and they present such resistance to the air that they decrease the speed when a ship is fighting under steam alone—which is the only way in which a ship can fight. Moreover, if a war ship should be caught under sail by a hostile war ship under steam alone, she would simply be in the position of a ship unprepared meeting a ship thoroughly prepared to fight; and while she had her men aloft furling sail and "clearing ship for action," the other could be knocking holes in her hull with heavyy guns, and killing the men aloft with Hotchkiss and Gatling machine guns.

SOME OFTEN NEGLECTED DUTIES OF THE ENGINEER.

By FRANCIS COLLINGWOOD, Am. Soc. C. E.

An Address before the Alumni of Rensselaer Polytechnic Institute.

In a recent address before the Institution of Mining Engineers, the subject of ethics, as bearing upon engineering practice, was treated with some fullness by the retiring president, Mr. Baylis. It is not my intention to repeat what he has so well said, or to take up the more obvious duties which are so often brought forward in addresses at the commencement season. Such addresses usually treat of those qualities which form the foundation of the character of every really successful engineer, and more especially of the necessity for that absolute honesty of purpose in every relation he holds, whether as designer, as supervisor, or as arbitrator, which alone can lead to the thoroughness of work, and which at once places him on his guard against any dishonest approach, however it may be disguised. Out of this one requirement spring all the *ordinary* duties of the profession; but passing these by we come to others more recondite, growing out of the relations of the engineer to the profession and to the world of science, and which seem more appropriate for consideration in addressing a society among whose members are men of large professional experience. These latter duties are none the less important, but in the hurry of active

life, they are too often overlooked or but imperfectly performed, and since every dereliction of duty is sure to react to our detriment, it the part of wisdom to guard watchfully against such in every direction.

Entering, then, upon our subject, and proceeding from the lesser to the greater, let us consider first the relations of the chief engineer of an important work to the members of his staff. As a matter of course he expects absolute loyalty on the part of all those under him, and any disloyalty would probably end in the prompt dismissal of the offender. How shall such loyalty be obtained? Shall it be the result of fear, or shall it be bred of mutual regard and confidence? In other words, is the duty *all* on the part of the subordinate, or is there a reciprocal obligation implied on the part of the chief? If the latter question be affirmatively answered, as it must be, let us proceed to state clearly what the obligation is. Here we should remember that the most eminent engineers have all been subordinates, and have had the help of others by which to rise. As an inevitable corollary upon this, it follows that the chief owes it to all in his employ to help them freely in their difficulties, and to be readily approachable. By thus doing he will make them stronger men professionally and help forward his own success. Our first duty, then, may be defined as that of politeness, affability, and a personal regard for subordinates. Mr. H. H. Richardson, of Boston the well-known architect, recently deceased, furnished a prominent example of one who nobly fulfilled this duty. In a notice of his life work, the *Sanitary Engineer* writes as follows:

"Nor less delightful than this office in the country was Mr. Richardson's relation to the draughtsmen he employed. Only those who have had the privilege of working under him can have much idea of the generous interest he took in their welfare and artistic progress, encouraging them and advising them in their studies, and ever ready to listen to intelligent suggestions, treating his men as personal friends rather than employes. Often he would invite a number of his older pupils to evening reunions, where he would talk over with them matters relating to their art. His valuable library and collection of photographs was always accessible to his draughtsmen, and he encouraged their constant reference to them. Few men have such power as he had of filling others with his own enthusiasm."

There is a second way in which the chief can help those under him, but to which selfishness often blinds his eyes.

It frequently happens in the progress of a work that the one coming in immediate contact with some of the many problems involved will bring out a solution or work up a design having real merit. The credit for such design does not belong to the chief, and, as a matter of simple justice, he should, in making up his reports, give full credit to the designer; yet, in many cases this is not done at all, and the assistant is mentioned in merely general terms and with no reference to his special work. This is not the way to obtain whole-hearted service; a chief engineer can *always* afford to be generous to his helpers. A full acknowledgment of all good work, no matter by whom done, in nowise detracts from his own standing; on the contrary, the world will think the better of him for it. The work is always known afterwards as that of the chief, and if he adds generosity to his other qualities, he will but stand the higher in the estimation of all thinking men. It is said that one great reason for the popularity of General Grant was, his generous treatment of all those under him.

There is yet another duty of the chief which has much to do with a hearty, loyal helpfulness on the part of subordinates. In the inception and progress of a work, it is he who in a great measure determines the respective salaries to be paid to the other members of his staff. The vicious doctrine that no more will be paid than the market will command, with no regard for the cost of living or for the character of the services rendered, too often prevails, and many men seem to think that if *they* are insured a good salary, it is laudable to cut the salaries of all below them down to the lowest attainable limit. It is only necessary to carry this doctrine to its ultimate conclusion to prove that it is both unjust and unwise. If we want a horse to do his fullest work we do not begin by scanting him in his food, but we give him full

provender and the best of care. Are men so different that we can expect them to do their best when they are but half paid for their labors? Is there not sure to be in their minds a rankling sense of injustice? If an assistant so paid be too honest to slight his work, he will still be preoccuppied by thoughts of "how to make both ends meet" in his expenses, or how to be able to meet just debts, possibly those incurred in obtaining the education which has fitted him for the very thing he is doing, and, as we all know, a preoccupied mind is not fitted for deep or consecutive thought on any subject. The chief should therefore insist at the outset upon full compensation for all services rendered, and should be the first to recognize good and faithful work, by asking for such increase in salary as may be consistent with its value. A man who lets neither time, study, labor, nor expense interfere with his attention to his duties, is certainly worth more than one who works always by the clock (trades unions to the contrary, notwithstanding); and a worthy man should not be obliged to ask for that which is rightly his due.

In immediate connection with the subject of organization of a staff arises that of a proper recognition of the relative position of subordinates; by this is meant the military idea that orders shall be issued and reports received always through those next in rank, and not, as is too often done, with an entire disregard of precedence or system. An engineer has a right to suppose that each one in his place is attending to his duties, and to pass over the one next below him and give an order to a minor, implies a lack of confidence in the first, is likely to cause insubordination in the second, and is sure, eventually, to introduce confusion and ill-feeling in the staff. Having placed a man in position he should be held stricty accountable for all work entrusted to him, and if found unfaithful he should be removed; but to pass him by and ignore him, whether by attempting to do the work personally, or by assigning it to others, is an evidence of weakness, and is doing one wrong to mend another.

Such abuse of good management is, however, often committed where no *fault* is attributed, in which case it shows a lack of sound ideas as to administrative methods, and is still to be unqualifiedly condemned. Not only does it introduce discord into the service, but in just so far as a man misdirects the labors of those under him and relieves them of their due share of responsibility, does he injure his own efficiency and make his own labors heavier. Here it may not be amiss to quote with proper reservation the advice that has been given engineers to "never do yourself what you can get others to do for you." In a recent obituary notice of a prominent English engineer the following sentence appropriate to the case in point occurs: "The confidence reposed by Mr. Leather in his staff, and the freedom with which its members were thus enabled to grapple with the many sudden emergencies inseparable from sea-works, were also important factors of his success in these undertakings."

It not unfrequently happens that boards of direction and other employers show a lack of this confidence in their chief engineer, and are guilty of the gross impropriety of attempting to give personal directions to assistants, or of receiving reports from them.

The practice cannot be too strongly reprehended. It is an axiom in physics that two bodies cannot occupy the same place at the same time, and it is no less true that two *persons* cannot attend to one and the same set of duties at once. Confusion is inevitable. "Dual control" is bound to be a failure wherever undertaken.

The subject of reciprocity of duties between the employer and employed (or, as a special case, between the engineer and his assistants) is one that is assuming greater prominence now than ever before in the world's history. Men are slowly learning that the rule of selfishness is inevitably and always *misrule*, and that in the complex relationships of our modern civilization, a wrong done to one class is bound in some way to react on all other classes. Heretofore the wealthy and powerful have been the oppressors, but now the laboring man has learned the lesson so well that he takes delight in entering into a *worse* bondage, in order that, by the might of numbers, he may inflict loss on those whom he conceives to be his enemies. It is evident

that peace and industrial harmony can be again established only on the higher principles of confidence, co-operation, mutual helpfulness, and good will; in other words, on the golden rule of doing as you would be done by. As has been recently so eloquently said by Bishop Potter: "When capitalists and employers of labor have forever dismissed the fallacy, which may be true enough in the domain of political economy, but is essentially false in the domain of religion, that labor and the laborer are alike a commodity, to be bought and sold, employed or dismissed, paid or underpaid, as the market shall decree; when the interest of workman and master shall have been owned by both as one, and the share of the laboring man shall be something more than a mere wage; when the principle of joint interest in what is produced of all the brains and hands that go to produce it is wisely and generously recognized; when the well-being of our fellow men, their homes and food, their pleasures, and their higher moral and spiritual necessities, shall be seen to be matters concerning which we may not dare to say, 'Am I my brother's keeper?' then, but not till then, may we hope those grave social divisions concerning which there need be among us all, as with Israel of old, 'great searchings of heart,'" may cease. But let us return from this episode.

We have thus far discussed what might be called the *family* relationships of the engineer, and more particularly those reaching downward, the duty of each man to lend a helping hand to all below him on a work, thus insuring the highest efficiency of the staff, and doing incidentally a still better thing, helping all to be stronger and more useful men. There is, however, a larger company, of which every engineer forms an integral part and to which he owes certain duties —viz., the profession as a whole; and to this I would next direct your attention.

Here, as in the engineering family, the golden rule should equally guide our actions. Perhaps one of the first ways in which this rule is violated is in passing judgment upon the works of others, in the way of fault-finding and belittling them, picking flaws, making small criticisms of design or methods, etc.

Does any engineer imagine he raises himself in the opinion of others by so doing, or in any way advances his own prospects of success? It cannot be; the world is, on the whole, fair in its estimate of man; it recognizes and appreciates the generous everywhere, and is just as sure to condemn the opposite. Criticism for the purpose of suggesting improvement is a good thing, but criticism for any other purpose is unworthy a true man. The best of men make mistakes, and are made stronger and better by them, and they suffer quite enough mortification from self-condemnation without the animadversion of men frequently of less calibre or purity of purpose. It has been laid down as a rule that the man who has never made a mistake must have had so limited an experience in work that he is not a safe man to trust.

But the subject of professional honor and generosity leads us to a *second* thought—we are bidden on Divine authority to look upon "the things of others," as well as our own, and this will lead us to hold to a high standard in the matter of engagements.

It is, of course, unprofessional, as well as ungentlemanly, to do anything to undermine another for the purpose of supplanting him; but I think we may go a step *further*, and say, where a man has been wrongfully discharged because he would not be made a tool of, either in the way of deceiving the public by doctored reports, by winking at dishonesty in whatever form, or for any other disreputable purpose, we may, indeed we *should*, refuse to accept such position, and so uphold our brother in his protest. As a matter of right, also, an offer should not be entertained for the position filled by another, unless his resignation has already been announced. In other words, if the profession is ever to assume its true dignity as a profession, we must never on our part do aught to bring it into discredit, and we should resent the idea that is held by many, that engineers are tools, or a commodity to be bought and sold, and are entitled to no more consideration than a man who is hired by the day.

The matter of engaging engineers has latterly taken a new phase, which puts this mercantile view in a still stronger light. It is nothing less than asking en-

gineers to bid against each other, for employment. I think I speak the voice of the Rensselaer Society of Engineers, and of the best engineers generally, when I say that they will not *knowingly* enter into such competition. A doctor or a lawyer who would condescend to thus act would be justly considered as unworthy of confidence, and why not an engineer, whose position is eminently a confidential one? A large Western city recently sent letters to a number of the most prominent engineers of established reputation, and whose works were well known, asking them to send a history of their professional experience and of their qualifications to do a certain work, saying that their names had been mentioned in connection with it as engineer. An alderman, not an engineer, was also sent to visit each man, and report. I happen to know at least *one* veteran engineer replied that his work had been before the public for about fifty years, and if *it* did not speak for him, *he* could not speak for himself. Is it too much to say that we owe it not only to ourselves, but to the profession, to make a strong protest against all such indignities? Has it come to this that a well-earned reputation for honesty, thoroughness of work, and ability as an engineer, shall all pass for nothing, and that a man must furnish his autobiography every time he enters a new engagement? Some of the very best men are noted for their modesty, and such a rule once established would result only in advancing those whose chief acquirement is playing a solo on a well-known instrument made usually of brass.

The old times when a man who could measure a ten-acre lot was called an engineer have nearly passed away (we cannot say entirely), and we now have as engineers a body of trained men, with keen intellects, who have taken pains to fit themselves in the most thorough manner for the conduct of work. The responsibilities they are called upon to assume are *many times* those assumed by any other profession, whether we contemplate them as they affect human life and happiness, or in the financial aspect alone; and shall we allow ourselves to be viewed in the light of mere laborers, and nothing more, on the rule of "so much work, so much pay?" I am sure you will all say no to this—emphatically, no; but we can rise no higher so long as we remain a mere mass of units, with no cohesion, each striving to get ahead of others, with no care for the hindmost. We must cultivate an *esprit de corps*, by which we shall come to feel that if one suffers all suffer, by which the world shall know that we do not work merely for hire, and by which we shall make ourselves felt as fully entitled to recognition as professional men, and to be treated accordingly. Nevertheless, it is true that we must live by our profession, and unless we set a proper financial value upon our services others will not do it for us. It is the duty of every engineer to make his charges to bear a reasonable proportion to the value and importance of the service rendered. That engineers have failed in this regard is evidenced by the fact that almost without exception our best engineers *never* acquire a competence by the legitimate practice of their profession. Like other men, they are sometimes fortunate in an outside speculation, and many abandon the profession and seek for larger returns as contractors; but this does not invalidate the fact that the professional practice of the engineer in this country is *not* remunerative. That this is not a necessity is shown by the many engineers in foreign lands who become men of wealth and influence. *There*, when a man builds a large and important work, he is knighted and made much of (the latest instance being the knighting of Sir James Brunlees on the recent completion of the tunnel under the Mersey, at Liverpool); here he is discharged at perhaps a month's notice, and often before he has had an opportunity of putting on those last finishing touches of which the necessity is not known by his successor, or which are utterly neglected by him. Salaries of $250 per day, and even more, for a month continuously, are not uncommon among English engineers, but such fees are unheard of here. American *architects* have gradually come to the agreement to charge five per cent. upon the total cost of a work for plans, specifications, estimates, detailed drawings, and such superintendence as is needed to insure a proper rendering of the specifications; but this does not include the payment of a clerk of works, or for extra

services in the matter of securing site or anything outside of the work itself, and the charge is greater on small buildings. In the matter of the Tower Bridge, in London, now under construction, the general design was made by the City Architect, but the engineering features were worked up by an engineer. The total estimated cost, as presented to Parliament, was over $3,000,000, and, after considerable controversy, the sum of $150,000, or five per cent. on the estimate, was voted by the Court of Common Council as the rightful payment for the service, to be divided between the architect and engineer as they might agree. This was spoken of as being the "standard commission." Now, while it may not be practicable for us to make this a standard at the present, there is no reason why it may not be a guide where there is no other. Those who have not considered the matter will be startled at the difference between this and the amounts our engineers ordinarily receive. Of course, such a standard cannot be reached in a moment; but it will never be reached if no effort is made. It is not the part of prudence to attempt reforms by violent changes, and I would be far from recommending anything like the unwise methods too often pursued, but we should all set our faces in the right direction. Let the community learn that the engineer must be an educated man; that to meet the ever-widening calls upon his skill made necessary by the great works of recent times, and the greater ones following on every advance accomplished, he must call to his aid all science, both ancient and modern; that he must know of the labors of others and use them to the best interests of his fellow men, and that the widest scholarship is now a necessity, and, when this lesson is learned, men will begin to understand that engineering is *indeed* a profession, and worthy of all the emoluments so freely accorded to the other learned professions in the land. It is but just that since from his position as judge and arbiter on the enterprises he helps to develop, he is precluded from investing in them, he should be fully paid for professional services.

In connection with the question of a high standard of professional honor arises a practice (to be deprecated) which is sometimes indulged in, of an engineer acting as adviser and recommending in that capacity an article of which he is the patentee, or in which he is personally interested. An engineer has no right to have any other interest than that of his employer; he degrades the profession and brings discredit upon it whenever he allows himself to be placed in a position where he is actuated by divided motives. He may come forward *avowedly* as the advocate of a special contrivance or method, and be entirely blameless, but he may *not* accept service as an engineer, and while acting as such, so shape reports or designs as to favor his own interests. An anecdote is related of Mr. Alfred W. Craven, when engineer of the Croton aqueduct, that at one time he had a water meter brought to his notice very favorably, and with the request that he take $1,000 of the stock. He said he had no money, but the promoter said that need make no difference, *he* would see to that. As the man left the room, Mr. Craven said: "There is one thing I want to say before you leave, that so long as I am in the department no meter that I am interested in can ever be introduced on the work." And it never was.

There is another indirect injury done to the profession, which is caused by the rivalry between the large firms connected with the building of bridges and other engineering operations. These furnish information and designs presumably without pay, but really the cost enters into expenses, and has to be charged on the cost of the product. There is much to be said on both sides of this question. Uniformity of design certainly tends to cheapen production, but there will also be a tendency to a sameness of thought and to quenching the spirit of investigation and progress. Centralization is the inevitable sequence of the effort to furnish such work at the lowest cost, and the engineers, who are the brains of such establishments, lose their individuality and become but parts of a great machine. It is quite certain that the fairest way of treating the matter would be for a reasonable charge to be always made for designs so furnished.

I come next to a duty which by many seems never to have been even thought of. I refer to the obligation resting upon every man to make known the results of

all professional practice, which have novelty or are of value for any other reason. Here the selfish spirit is too apt to rule, with the underlying idea that if technical knowledge be made public others will seize upon it, and by competition interfere with the chances of employment that would otherwise ensue upon exclusive control. It may be questioned whether, even upon this low plane of self interest, one's purposes are not best served by publicity. As between a man who has made it evident both practically and by proper publication that he *knows* how to do a certain thing and a man who follows confessedly as a copyist, the first will assuredly be the most likely to be sought out when the same problem is presented a second time. Numerous instances could be pointed out of recent occurrence, but it is not desirable to go further in this direction; we are not concerned at the present with the financial but with the *ethical* question—what is our duty? A digression may here be pardoned for the purpose of pointing out the position which every professional man holds as a unit in the great mass of humanity, as a factor in our modern civilization, and as a debtor to the world of science, literature and art—to do what he can to repay in kind that which he has so bountifully received. He cannot "live to himself alone," even if he would. From the time of his birth he is under the protection of laws which are the outgrowth of centuries of thought and experience, reacted upon, ameliorated, and molded by the principles of the Christian faith. He is under "tutors and masters" who spend time and labor in correcting his mistakes, showing him the sources of knowledge and leading him by plain paths to the fountain-head. If the labor of others for all the years gone by had not supplied that fountain, in vain would he seek to drink. Generous men everywhere have recorded facts, experiments, theories, experiences, designs, statistics, in order that he "may enter into their labors," and progress from the high vantage ground thus ready to his hand. In view of all this, can any man rightly say that *he* has no duty to perform in return? or what he discovers is his own, and he will keep it to himself? I verily believe that it is lack of thought which allows the experience gained on so many important works to pass into oblivion and be lost to the world. Lack of time is the usual excuse, but lack of inclination is in many cases the real reason. Whatever it may be, let us see to it that we are not among the delinquents. I would not urge that this be done in a spirit of pride; on the contrary, when a man thinks soundly on such matters and sees how really little of his work is entirely his own, he must ever feel humbled. I would, however, that every one shall feel it to be a sacred duty to record his professional experiences in some proper way, by reports, by papers to societies, or by discussions in technical journals, for the benefit of those who shall follow him. The publishing of full reports might be made more common if we were always faithful in urging the duty upon boards of direction, and such reports are considered by engineers the most satisfactory sources for the latest professional information.

The last duty to which I propose to call your attention is a very practical one, which in several very prominent instances of late has been but imperfectly performed. I refer to the obligation always resting upon an engineer, of making all statements on which proposals are asked in lettings of work, clear and unmistakable. All specifications should be explicit, and state, as nearly as language can, just what the contractor will be called upon to do, and all information attainable as to the nature of the site, difficulties of foundation, etc., should clearly set forth. In doing this the engineer should remember that the contractor also has rights which should be fully cared for, and not try to get an undue advantage by any trick of language. One of the cases referred to in which this duty was imperfectly performed was in the specifications issued for the Hawkesbury Bridge, now under contract to be erected near Sydney, in New South Wales, and which will be the most important structure yet undertaken in the Southern Hemisphere. Here is a bridge which is to cost over one and a-half millions of dollars, and of which, in referring to the designs submitted, London *Engineering* says as follows: "A bare glance at the designs shows either the piers are unnecessarily massive in some cases, or undoubtedly too slender in others. This

great want of uniformity is due, no doubt, to a limiting pressure on the foundations not being specified in the conditions, though minute instructions were given for the superstructure. It seems probable that this lack of information or of conditions regarding the doubtful and most costly portion of the work, may be a reason why so few firms known as bridge builders appear to have availed themselves of the opportunity of tendering, so reducing the competition, to the *disadvantage* of the colony." In a large work nearer home, a somewhat similar experience has been had, if reports in the papers are to be credited. It seems almost a truism to say an engineer is unfaithful to duty, whenever he allows vagueness to enter in any form into his work, especially in so important a matter as a specification. I know that an engineer is often hurried to bring forth results, and to try sometimes to accomplish impossibilities in the matter of speed; but an energetic protest would in most cases secure the time required; and when it is made perfectly clear that uncertain borings and insufficient examination as to site, indistinctness in requirements or immature plans, will be invariably followed by an increase in amount of bids to cover the factor of ignorance, there are few boards which cannot be influenced to a right decision. An engineer is not responsible for additional cost, when too short a time is allowed for proper development of a scheme, or when plans are substantially changed after estimates are made; but he is justly held accountable for wide departures from estimates when time is given for full preparation.

I have thus brought before you some of the ways in which the best of us are at times found wanting. In the rush and turmoil of active practice, and the rapid advances the profession is making in all directions, it behooves us at times to pause and see whither we are drifting, and to adjust our lives anew to the increased responsibilities thrown upon us. We are not alone in this regard. Men of all other professions may take some portion of these lessons to heart. As men and citizens, unless we enter fully into the idea and the desire that the world may be in some measure made better and happier from our having lived in it, we have not only much to learn, but we are missing the chiefest end of our existence. We shall reach our most perfect manhood only as we do *all* our work under the fullest appreciation of the meaning contained in that one word—*duty*.

REFRIGERATING AND ICE-MAKING MACHINERY AND APPLIANCES.

By T. LIGHTFOOT.

Read before the Institution of Mechanical Engineers.

I.

The subject of refrigerating and ice-making machinery has not hitherto, so far as the author is aware, been dealt with in a comprehensive manner by any engineering society. The purpose, therefore, of the present paper is to describe the various systems at present in use, giving also short sketches of their development, together with some considerations respecting their practical application and working, in the hope that this may prove an acceptable contribution to the *Proceedings* of the institution, and lead to a profitable discussion upon a subject, the importance of which is daily becoming more manifest.

The primary function of all refrigerating and ice-making apparatus is to abstract heat, the temperature of the refrigerating agent being of necessity below that of the substance to be cooled. It is obvious, however, that, without provision either for rejection of the heat thus abstracted, or for renewal of the refrigerating agent, equalization of temperature would ultimately ensue, and the cooling

action would cease. In practice, if the machine is to work continuously, one or other of these means must be adopted; and a complete refrigerating machine therefore consists of an apparatus by which heat is abstracted, in combination either with some system for renewing the heat-absorbing agent, or, as is more usually the case, with a contrivance whereby the abstracted heat is rejected, and the agent is restored to a condition in which it can again be employed for cooling purposes. The subject can be conveniently dealt with under the four following heads:

1. Apparatus for abstracting heat by the melting of a solid.
2. Machinery and apparatus for abstracting heat by the evaporation of a more or less volatile liquid.
3. Machinery by which a gas is compressed partially cooled while under compression, and further cooled by subsequent expansion in the performance of work, the cooled gas being afterwards used for abstracting heat.
4. Considerations as to the applications of the various systems.

I.—*Apparatus for Abstracting Heat by the Rapid of a Solid.*

This is probably the oldest method of artificial cooling. When a substance changes its physical state, and passes from the solid to the liquid form, the force of cohesion is overcome by the addition of energy in the form of heat. The effect may be produced without change in sensible temperature, if the heat be absorbed at the same rate as it is supplied from without, Thus, as is well known, the temperature of melting ice remains constant at 32° Fahr.; and any increase or decrease in the heat supplied merely hastens or retards the rate of melting, without affecting the temperature. Mixtures of certain salts with water or acids, and of some salts with ice, which form liquids whose freezing points are below the original temperatures of the mixtures, do not, however, behave in this way; for under ordinary circumstances the tendency to pass into the liquid form is so strong, that heat is absorbed at a greater rate than it can be supplied from without. The store of heat of the melting substances themselves is therefore drawn upon, and the temperature consequently falls until a balance is set up between the rate of melting and the rate at which heat is supplied from outside. This is what takes place with ordinary freezing mixtures. The amount of the depression in temperature appears to depend to some extent on the state of hydration of the salt, and the percentage of it in the mixture. Almost the only salts used are those of certain alkalies, few others possessing the requisite solubility at low temperatures. A list of the freezing mixtures usually employed is given in the appended table I.

Such a method of abstracting heat is extremely convenient for the laboratory, and for some other special purposes. Attempts have also been made to apply it commercially on a large scale for the manufacture of ice and for cooling. The late Sir William Siemens constructed an ice-making apparatus in which calcium chloride was employed. The reduction in temperature produced by this salt in water is about 30° Fahr.; but as this was not sufficient for freezing when the initial temperature of the water was about 60° or 65° Fahr., a heat interchanger was introduced, by means of which the spent liquor at about 30° was utilized for cooling the water before it was mixed with the salt; and to the extent of this cooling the degree of cold produced was intensified. The salt was recovered by evaporation, and used over again. Although this apparatus worked well and produced ice, the inventor himself considered the process inferior to mechanical methods, and abandoned it. In the Toselli machine a mixture of ammonia nitrate and water is used, by means of which a reduction in temperature of about 40° Fahr. is obtained. The apparatus consists of a vessel in which the solution of the salt is effected, and an ice can containing several slightly tapering molds of circular cross section and of varying sizes. The molds being filled with water are introduced into the freezing mixture; and in a few minutes ice is formed round the edges to the thickness of nearly an eighth of an inch. The rings or tubes of ice are then removed and placed one within the other, so forming a small stick of ice.

Ammonium nitrate is also employed in a machine recently brought out in the United States for the production of ice

on a large scale. In one form of this apparatus, intended chiefly for domestic purposes, a series of annular vessels, one within the other, is used; the molds in which the ice is to be formed being placed in the center. The reduction of temperature produced by the freezing mixture in in the outermost vessel cools the water in the second; and this, on salt being added, cools the third; and so on. In this way the cold is very much intensified at the center, and a low temperature can be produced independent of the initial temperature of the water. The number of rings employed varies according to the effect to be produced and the conditions under which the apparatus is applied. The annular vessels, together with the ice molds, are carried in a wood casing supported on bearings, the only motive power required being that necessary to rotate the vessels slowly, so as to promote the solution of the salt. Another form of apparatus, designed for continuous use on a large scale, consists of a vessel into which ammonium nitrate is automatically fed, and in which it enters into solution with water previously cooled in an interchanger by the spent liquor, after the latter has left the ice-making tanks or cooling-rooms. The cold brine thus produced is circulated by a pump through the ice-tanks, or through pipes placed in the rooms it is desired to cool; and is returned through the interchanger to an evaporating tank, where by means of heat the water is driven off and the salt recovered. This is practically Sir William Siemens' apparatus in a somewhat extended form. The cost of producing 15 tons of ice per twenty-four hours with such an apparatus of suitable capacity is stated at 7s. per ton, with good coals at 15s. a ton, and exclusive of depreciation and repairs. This, however, is probably much too low an estimate, being based on the erroneous assumption that 1 lb. of coal is capable of evaporating 20 lbs. of water. Nearly the whole of the coal is used for evaporating the water in recovering the salt, the quantity being given at 2½ tons of coal for every 15 tons of ice. If however, this has been calculated on an evaporative duty of 20 lbs. of water per lb. of coal, the amount actually used will probably be about 5 tons of coal, which would make the cost per ton of ice 9s. 3d. instead of 7s. On the other hand, it must be remembered that under certain climatic conditions much of the water could be evaporated in the open air, without the use of fuel; in which case the coal consumption, and therefore the cost of ice production, would be greatly lessened.

II.—*Machinery and Apparatus for Abstracting Heat by the Evaporation of a more or less Volatile Liquid.*

When a liquid changes its physical condition, and assumes the state of vapor, heat is absorbed in increasing the energy of the molecules. This heat is absorbed without change in sensible temperature; and the amount thus disposed of is usually called the latent heat of vaporization. For different liquids different quantities of heat are required; and for the same liquid the amount varies somewhat according to the pressure at which vaporization occurs. Other things being equal, the liquid with the highest latent heat will be the best refrigerant, because for a given abstraction of heat the least weight of liquid will be required, and therefore the power expended in working the machine will be the least. The principal systems in which the evaporation of liquids is employed may be treated under the following subdivisions:—

A. Apparatus in which the refrigerating agent is rejected along with the heat it has acquired.

B. Machines in which heat only is rejected, the refrigerating agent being restored to its original physical condition by means of mechanical compression, and by cooling when under compression.

C. Apparatus in which heat only is rejected by allowing the refrigerating agent to change its physical condition by entering into solution with a liquid, from which it is afterwards separated by evaporation and recovered.

D. Machinery and apparatus in which heat only is rejected, by changing the physical state of the refrigerating agent by a combination of both mechanical compression and solution, with cooling.

System A.—This is generally known as the vacuum process, for as the refrigerating agent itself is rejected, the only

agent of a sufficiently inexpensive character to be employed is water, and this, owing to its high boiling-point, requires the maintenance of a high degree of vacuum in order to produce ebullition at the proper temperature. The vapor tensions of water at temperatures up to boiling-point at atmospheric pressure are given in the appended table II., from which it will be seen that at 32° Fahr. the tension is only 0.089 lb. per square inch. In ice-making, therefore, a degree of vacuum must be maintained at least as high as this. The earliest machine of this kind appears to have been made in 1755, by Dr. Cullen, who produced the vacuum by means of an air-pump. In 1810 Leslie, combining with the air-pump a vessel containing strong sulphuric acid, for absorbing the vapor from the air drawn over and so assisting the pump, succeeded in producing an apparatus by means of which 1 to 1½ lbs. of ice could be made in a single operation. Vallance and Kingsford followed later, but without practical results; and Carré, many years afterwards, embodied the same principle in a machine for cooling and for making small quantities of ice, chiefly for domestic purposes. His machine, which is still sometimes used, consists of a small vertical vacuum pump, worked by hand, either by a lever or by a crank, which exhausts the air from the carafe or decanter containing the water or liquid to be frozen or cooled. Between the pump and the water vessel is a lead cylinder, three-quarters full of sulphuric acid, over which the air, and with it the vapor given off from the liquid, is caused to pass on its way to the pump. The vacuum thus produced causes a rapid evaporation, which quickly lowers the temperature of the water; and if the action is prolonged for about four or five minutes, the water becomes frozen into a block of porous opaque ice. The charge of acid is about 4½ pints, and it is said that from 50 to 60 carafes of about a pint each can be frozen with one charge. So long as the joints are all tight and the pump is in good order this apparatus works well; but in practice it has been found troublesome and unreliable, and consequently has never come into anything like general use.

In 1878 Franz Windhausen, of Berlin, brought out a compound vacuum-pump for producing ice direct from water on a large scale, without the employment of sulphuric acid; and also an arrangement in which sulphuric acid could be used, the acid being cooled by water during its absorption of the vapor, and afterwards concentrated, so that a fresh supply was rendered unnecessary. This apparatus was improved on in 1880; and in 1881 a machine nominally capable of producing 15 tons of ice per twenty-four hours was put to work experimentally at the Aylesbury Dairy, at Bayswater, being afterwards removed to Lillie Bridge, where the author believes it now is. The installation was fully described and illustrated by Carl Pieper in a paper read before the Society of Engineers, in November, 1882, and by Dr. John Hopkinson, at the Society of Arts, about the same time.* It consists of six slightly tapered ice forming vessels of cast iron, of circular cross section, closed at their bottom ends by hinged doors with air-tight joints, into which water is allowed to flow at a regular speed through suitable nozzles, the cylinders being steamjacketed in order to allow the ice to be readily discharged. The upper parts of these vessels communicate with the pump through a long, horizontal iron vessel of circular section containing sulphuric acid which, when the machine is in operation, is kept in continual agitation by means of revolving arms. The acid vessel is surrounded with cold water which carries off most of the heat liberated during the absorption of the vapor. The pump has two cylinders, one double-acting of large size, and a smaller single-acting one. The capacities of these cylinders per revolution are as 62 to 1. The air and whatever vapor has passed the acid are drawn into the large pump, which partially compresses and delivers them into a condenser. Here part of the vapor is condensed by the action of cold water, the remainder passing along with the air to the second pump, where they are compressed up to atmospheric tension, and discharged. The advantage gained by the use of a compound pump is due to the action of the intermediate condenser, and to the compression being performed in two stages, by which the losses from

* *Transactions of the Society of Engineers*, 1882, page 145; *Journal of the Society of Arts*, 1882, vol. xxxi., page 20.

the clearance spaces in the large pump are rendered much less than they would be if compression to atmospheric pressure were accomplished in a single operation. The effect of the pump is said to be such that a vacuum of half a millimeter of mercury, or about 0.0097 lb. per square inch, can be continuously maintained; though, in actual work about 2½ millimeters, or 0.0484 lb. per square inch is as low as is necessary. The concentration of the acid is effected in a lead-lined vessel, in which is a coil of lead piping heated by steam, the pressure in the vessel being kept down by means of an ordinary air pump. No acid pump is needed, as the transfer from one vessel to another is effected by the pressure of the atmosphere. The comparatively cool weak acid on its way to the concentrator is heated in an interchanger by the strong acid returning from the concentrator. Six blocks of ice, each weighing about 560 lbs., are formed in about twenty minutes after starting. The charge of acid is said to serve for three makings of ice, after which it becomes too weak, and requires to be concentrated.

The water being admitted into the ice-forming vessels in fine streams offers a large surface for evaporation, and is almost immediately converted into small globules of ice, which fall to the bottom and become cemented together by the freezing of a certain quantity of water that collects there. This water being in a violent state of ebullition, the ice so formed is not solid, but contains spaces or blowholes, which, as soon as the block is discharged from the vessel, become filled with air and cause opacity. Several attempts have been made to produce transparent ice by the direct vacuum process, but so far without success. Distilled water, or water deprived of air has been tried, and hydraulic pressure has been used for compressing the porous opaque blocks, but neither plan has been found practicable commercially. It would appear, indeed, that the only way to make clear ice by the vacuum process is by forming it in molds, subjected externally to the action of brine previously cooled by the evaporation of a portion of its water. The cost in this case would necessarily be greater; but the ice would be solid and transparent and would consequently have a higher commercial value. The latent heat of liquefaction of water being 142.6° Fahr., the total heat to be extracted in order to produce 1 ton of ice from 1 ton of water at 60° Fahr., is 382,144 Fahr. lbs. units. Taking the latent heat of evaporization of water at 32° Fahr. to be 1091.7, it is obvious that 350 lbs. must be evaporated to make the ton of ice. But, in addition, the sensible heat of evaporated water, which entering at 60° would leave at about 32°, would have to be taken off, and this would require the evaporation of about 9¼ lbs. more, making a total of about 360 lbs, without allowance for loss by heat entering from without, which would be considerable. The total water actually used is given by Mr. Pieper at 12 tons per ton of ice, including the quantity required for cooling purposes. The fuel consumption is stated to be 180 lbs. of coal per ton of ice, but the author understands a much larger quantity is actually required. It is consumed for generating steam for driving the vacuum pump and the concentrator air pump, and for evaporating the water absorbed by the acid. According to Dr. Hopkinson, the cost of making 1 ton of opaque ice is 4s.; but the author believes experience has shown that a much higher figure is required to cover the necessary expenses for repairs and maintenance, which in some parts of the apparatus are very heavy. Windhausen's machine has not met with any extended application in this country, owing, no doubt, to the opaque and porous condition of the ice produced by it, and to the large and cumbrous nature of the plant, which must doubtless require great care and supervision in working.

A vacuum apparatus for refrigerating liquids by their own partial evaporation, and for making ice, was brought out in 1878 by James Harrison. Its chief feature is the revolving cylinder or pump, which affords a simple and efficient means of exhausting large volumes of vapor of low tension, without incurring the loss from friction of ordinary piston packings, and the trouble of keeping them tight and in good working order, while at the same time the first cost is much reduced. The pump consists of a hollow iron cylinder, revolving on a horizonal axis, and divided into compartments by longitudi-

nal compartments of L section. It is partially filled with a non-evaporable or one which evaporates only at a temperature considerably in excess of that at which the refrigerating liquid is evaporated, and which is also chemically neutral to the vapor that is brought in contact with it. In practice, oil is the liquid used. The refrigerating or ice-making vessels, of any convenient form, are connected by a pipe with one end of a fixed hollow axle on which the cylinder revolves; and inside the cylinder another pipe rises up above the level of the liquid the longitudinal partitions being stopped short at one end to enable this to be done. The compartments move around mouth downwards, carrying with them the vapor with which they are charged, and compressing it to an extent measured by the distance they dip below the surface of the liquid, until, when the lowest position is approached, the compressed vapor is liberated, and rises into a fixed hood near the center, in communication with a second hollow axle at the opposite end of the cylinder to that at which the vapor enters. Through this second axle the compressed vapor passes to a surface evaporative condenser, in which it is partly condensed by the combined action of direct cooling and the partial evaporation of water trickling over the surface; the water of condensation, together with any air, is then compressed to the tension of the atmosphere by a small pump, and discharged. By this process, the author is informed, it is expected to produce opaque ice on a large scale at a cost of about 1s. per ton. The fuel consumption will certainly be very small, because friction, which is a large item in the Windhausen apparatus, is here to a large extent eliminated. There would also be a saving of all the fuel used in concentrating the acid, and of much of the water required for cooling purposes, besides a reduction in the first cost of the plant, and in the expense of maintenance.

System B.—This is known as the compression process, and is used with liquids whose vapors condense under pressure at ordinary temperatures. Although, prior to 1834, several suggestions had been made with regard to the production of ice and the cooling of liquids by the evaporation of a more volatile liquid than water, the author believes that the first machine really constructed and put to work was made by John Hague in that year, from the designs of Jacob Perkins. According to Sir Frederick Bramwell,* the liquid used was one arising from the destructive distillation of caoutchouc. The machine, so far as the author is aware, was never put to work outside of the factory where it was constructed. The water to be frozen was placed in a jacketed copper pan, the jacket being partially filled with the volatile liquid, and carefully protected on the outside with a covering of non-conducting material. A pump drew off the vapor from the jacket, and delivered it compressed into a worm, around which cooling water was circulated, the pressure being such as to cause liquefaction. The liquid collected at the bottom of the worm, and returned to the jacket through a pipe, to be again evaporated. This apparatus, though in some respects crude, is yet the parent of all compression machines used at the present time, the only improvements made since the year 1854 having been in matters of constructive detail. The next advance was made in 1856 and 1857, by James Harrison, who brought out a machine embodying the same principles as that of Perkins, but worked out on a larger and more practical scale. It was taken up by the late Mr. Siebe, and was the first ice-making machine that really came into practical use in this country, and was employed on a commercial scale. An improved apparatus of this kind, in which ether is used as the refrigerating agent, is still manufactured by Messrs. Siebe, Gorman & Co. The vapor tensions of ether are given in the appended Table II. It is not a very volatile liquid, of specific gravity 0.720, having a latent heat of evaporization of 165°, and a specific gravity of vapor of 2.24 compared with air. Its boiling-point at atmospheric pressure is 96° Fahr. Messrs. Siebe, Gorman & Co.'s machine, applied to the manufacture of clear ice, consists of a refrigerator, a water-jacketed pump, driven by a surface-condensing steam-engine, an ether-condenser, and ice-making tanks containing copper molds, around which brine, cooled to a

* *Journal of the Society of Arts*, 1882, vol. xxxi., p. 77.

low temperature in the refrigerator, is circulated by a pump. The refrigerator is a cylindrical vessel of sheet copper, containing clusters of horizontal, solid-drawn, copper tubes, through which the brine successively circulates. The shell is connected with the pump by a pipe, the liquid ether from the condenser being admitted through a small pipe having a cock, which is so adjusted as to pass the precise weight of ether that the pump will draw off. What this weight is depends entirely on the pressure at which evaporation occurs; the greater the density of the vapor, the greater is the weight drawn off at each revolution of the pump. The pressure at which evaporation occurs is defined by the temuerature to which it is de.ired to reduce the brine, the boiling-point of the ether being regulated so as to give the required reduction of temperature, and no more, otherwise the apparatus would not work up to its full capacity. The condenser consists of a cluster of solid-drawn copper tubes placed horizontally in a wood tank, through which cooling water is circulated, the amount of water required in this country being 150 gallons per hour for every ton of ice made per twenty-four hours. With the temperature of cooling water available in this country, liquefaction generally occurs at a pressure of about 3 lbs. per square inch above the atmosphere, but in a warm climate the pressure needed may reach as much as 10 or even 12 lbs.

In another apparatus the ice is made in cans or molds. The molds, of sheet copper or steel, are filled with the water to be frozen, and are suspended in a tank, through which is kept up a circulation of cold brine from the refrigerator. As soon as the ice is formed the molds are removed and dipped for a few minutes in warm water to loosen the ice, which is then turned out. The sizes of the molds vary a good deal, according to the capacity of the machine and the purpose for which the ice is to be used. A common plan is commence with a thickness of three inches for a production of 1 ton per twenty-four hours, and to go up to 9 inches for 10 tons and upwards. The thickness exercises an important bearing upon the number of molds to be employed for any given output; for while a 3-inch block can be frozen in eight hours, one 9 inches thick will take about thirty-six hours. The time, however, varies also according to the temperature at which the brine is worked. For an ether machine, such as that just described, the brine temperature may be taken at from 10° to 15° Fahr. Another method is that known as the cell system. This consists of a series of cellular walls of wrought or cast iron, placed from 12 to 16 inches apart, the space between each pair of walls being filled with the water to be frozen. The cool brine circulates through the cells, the ice gradually forming outside, and increasing in thickness until the two opposite layers met and join together. If thinner blocks are required freezing may be stopped at any time, and the ice removed. In order to detach the ice from the walls, it may either be left for a time after the circulation of the brine has been stopped, or a better and quicker plan is to pass some warmer brine through the cells. In order to produce transparent ice it is necessary that the water should be agitated during freezing, so as to allow the escape of the air set free. When molds are used, this is generally done by means of arms having a vertical or horizontal movement, which are either pushed up by the ice as it forms, leaving the block solid, or work backwards in the center of the mold, dividing the plock vertically into two equal pieces. With cells, agitation is generally effected from the bottom by means of paddles. The ice which forms first on the sides of the molds or cells is generally transparent enough, even without agitation. The opacity gradually increases towards the center, where the two layers meet and join together; agitation is therefore more necessary towards the end of the freezing process than at the beginning. As the quantity of air held in solution by water decreases as its temperature is raised, it is obvious that less agitation will be required in hot than in temperate climates; for this reason, in India and elsewhere, agitation is frequently dispensed with altogether.

Machines using ether as the refrigerating medium are also largely made by Messrs. Sidely & Co., of Liverpool, and Messrs. West & Co., of Southwark; but they present no special features which are not embodied in the apparatus already

described, the points of difference being in details to which it is not necessary to refer. As already stated, the working pressure in the refrigerator must depend upon the extent of the reduction in temperature desired, bearing in mind that the higher the pressure the greater will be the work that can be got out of any given capacity of pump. The liquefying pressure in the condenser depends on the temperature of the cooling water and on the quantity that is passed through in relation to the quantity of heat carried away; and this pressure determines the mechanical work to be expended. In any given machine the work may be accounted for as follows:

Friction.
Heat rejected during compression.
Heat acquired by the refrigerating agent in passing through the pump.
Work expended in discharging the compressed vapor from the pump.
Against which must be set—
Work done by the vapor entering the pump.

Assuming that vapor alone enters the pump, the heat rejected in the condenser is—

Heat of vaporization acquired in the refrigerator, with the correction necessary for difference in pressure.

Heat acquired in the pump, less the amount due to the difference between the temperature at which liquefaction occurs and that at which the vapor entered the pump.

Though circumstances vary so much that no absolutely definite statement can be made as to the working of ether machines in general, the following particulars, taken from actual experiment in this country, will serve to show what may be expected under ordinary conditions:

Production of ice, tons per 24 hours	15 tons.
Production of ice, lb. per hour	1,400 lbs.
Heat-units per hour abstracted in ice-making	245,000 units
Indicated horse-power in steam cylinder, excluding that required for circulating the cooling water, and for working crane, &c.	83 I. H. P.
Indicated horse-power in ether pump	46½ I. H. P.
Thermal equivalent of work in ether pump, units per hour	119,261 units
Ratio of work in pump to work in ice-making	1 to 2.05
Temperature of water entering condenser	52° Fahr.

Assuming the coal consumption per indicated horse-power to be 2 lbs. per hour, and the price of coal 15s. a ton, the total cost of producing transparent block ice in this country on the ether system, with such a machine as that just referred to, may be taken at about 5s. per ton, excluding allowance for repairs and depreciation. The production of ice would be about 8.3 tons per ton of coal. For cooling water and other liquids another machine is used; but in this case the ice-boxes are dispensed with, the liquid being passed direct through the refrigerator without the employment of brine. Methylic ether, a liquid with a latent heat of vaporization of—, and which boils under atmospheric pressure at 10 5° below zero Fahr., has been employed by Tellier in machinery of practically similar design to that used with ordinary ether. Tellier's apparatus has never come into use in this country, and need not be further dwelt on, for beyond the difference in size of pump, and the obvious alterations due to the higher working pressures, it presents no features of importance. Some years ago Raoul Pictet, of Geneva, successfully introduced sulphur dioxide as a refrigerating agent, and in France a large number of his machines have been made and put to work. In this country, also, they have been used, but to a much smaller extent. It is a liquid with a latent heat of vaporization of 182°, and under atmospheric pressure boils at 14° Fahr. This machine is also of similar design to those in which ether is employed; but Pictet combined the refrigerator with the ice-making tanks, the brine being circulated by means of a fan. In this way the space occupied was reduced, and the efficiency somewhat increased. The cost of producing ice by the Tellier and Pictet machines may be taken at practically the same as that by the other process. Some of the more volatile derivatives of coal tar have been used in compression machines, especially in the United States; but it will be unnecessary to refer to them in detail, as their application has been exceedingly limited.

Anhydrous ammonia, which may now

be obtained as an article of commerce, has of late years been very largely introduced as a refrigerating agent, more especially in Germany and in the United States. Under atmospheric pressure, anhydrous liquid ammonia boils at 37.30° below zero Fahr., and under this condition its latent heat of vaporization is 900°. So far as the cycle of operation is concerned, it is precisely the same as for either; the liquid is vaporised in the refrigerator by the action of the pump, which then compresses the vapor, and delivers it into the condenser at such pressure as to cause it to liquefy. In the construction of ammonia machines, however, there are two essential points of difference. For, in the first place, the pressure of the ammonia vapor is much higher than that of ether at the same temperatures, its tension at 60° Fahr. being 108 lbs. per square inch; and, secondly, owing to the action of ammonia on copper, no brass or gun metal can be used in any part with which the gas or liquid comes into contact. One of the chief difficulties encountered in the compression of ammonia is leakage at the pump gland. The gas is extremely searching, and even at the comparatively low pressure of 30 lbs. per square inch above the atmosphere it will readily find its way through an ordinary gland; while at the pressure existing in the condenser, which may be taken at from 150 to 180 lbs. per square inch, this tendency is of course much aggravated. In order to minimise the leakage and to simplify the construction of the gland, the pumps are frequently made single-acting, as in this way the gland is exposed only to the refrigerator pressure, which is seldom above 30 lbs. It is also usual for glycerine, or some lubricant that does not saponify with ammonia, to be injected into the pump, so as to form a liquid seal for the gland, and in some cases for the piston as well; this is the general practice in the United States. In Germany, on the other hand, where the compression machine has been very largely applied, the double-acting pump is more usual. To lessen leakage, Linde provides a chamber in the gland box, into which glycerine or some suitable lubricant is constantly forced at a slightly greater pressure than that prevailing in the condenser, so that the tendency is for the lubricant to leak inwards, instead of ammonia outwards. Any lubricant that does get into the pump passes out with the ammonia, and is separated from it in a suitable vessel. Up to the present time, so few ammonia compression machines have been constructed in England, that as yet no general practice has been established; but, on the whole, the feeling seems to be in favor of the single-acting pump.

With regard to the other parts of the apparatus, but little need be said. Wrought-iron coils or zig-zags are used for both the condenser and the refrigerator, their precise form depending on the fancy of the designer. The refrigerator is generally combined with the ice-tanks, the cooling pipes being placed either below or at the side of the molds, sometimes in a separate compartment and sometimes in the same tank. With the cell system an independent refrigerator is used, the cooled brine being circulated by a pump in a similar manner to that described for the ether system. Owing to the low temperature which may be attained by the use of ammonia, care has been taken in the selection of a brine that will not congeal with the degree of cold to which it will be subjected. A solution of calcium or magnesium chloride in water is generally used. The mechanical work expended in compressing ammonia may be accounted for in a precisely similar manner to that expended in the compression of ether. Notwithstanding that the degree of compression is so much greater with ammonia than with ether, the energy expended in compressing, heating, and delivering the gas is less, owing to the much smaller weight of ammonia required to produce a given refrigerating effect, the weights being in the inverse ratio of the heats of vaporization, or as one to 5.45. For this reason the cost of making ice is much less with ammonia than with ether, one ton of coal being capable of producing as much as 12 tons of ice in well-constructed ammonia apparatus having a capacity of 15 tons per 24 hours. With coal at 15s. a ton, the cost of making ice by the ammonia compression system may be taken at about 3s. 9d. per ton for a production of 15 tons per 24 hours, exclusive of allowances for repairs and depreciation. Through the

courtesy of the manager of the Linde British Ice Company, the author is enabled to give the following results of a test made by a committee of Bavarian engineers, with a machine erected in a brewery in Germany. The test, he believes was carried out in an impartial manner; and though it is not put forward by the Linde Company as showing the results attained in the ordinary working of their machines, it will nevertheless be of interest as indicating what may be expected under the most favorable conditions:

Nominal capacity of machine, tons of ice per 24 hours	24 tons.
Actual production of ice, tons per 24 hours	39.2 tons.
Actual production of ice, lbs. per hour	3,659 lbs.
Heat-units abstracted per hour in ice making	731,800 units
Indicated horse-power in steam cylinder, excluding that required for circulating the cooling water and for working cranes	53 I. H. P.
Indicated horse-power in ammonia pump	38 I. H. P.
Thermal equivalent of work in ammonia pump, units per hour	97,460 units.
Ratio of work in pump to work in ice-making	1 to 7.5
Total feed-water used in boiler, lbs. per 24 hours	26,754 lbs.
Ratio of coal consumed to ice made, taking an evaporation of 8 lbs. of water per lb. of coal	1 to 26.3

In this case the pumps were driven by a Sulzer engine, which developed one indicated horse-power with 21.8 lbs. of steam per hour, including the amount condensed in steam pipes. Ammonia compression machines are manufactured in this country by Messrs. Siebe, Gorman & Co., the Birmingham Refrigeration Company, and Linde British Ice Company.

System C.—This is known as the absorption process, and was first applied by Carré about 1850. The principle employed is chemical or physical, rather than mechanical, and depends on the fact that many vapors of low boiling-point are readily absorbed by water, but can be separated again by the application of heat to the mixed liquid. A considerable number of machines in which ammonia was used in combination with water as an absorbent were made by Carré in France; but no very high degree of perfection was arrived at, owing to the impossibility of getting an anhydrous product of distillation; the ammonia distilled over contained about 25 per cent. of water, which caused a useless expenditure of heat during evaporation and rendered the working of the apparatus intermittent. Taking advantage of the fact that two vapors of different boiling points, when mixed, can be separated by means of fractional condensation, Rees Reece brought out, in 1867, an absorption machine, in which the distillate was very nearly anhydrous. The action of the machine was briefly as follows: Ordinary liquid ammonia of commerce, of 0.880 specific gravity, was heated, and a mixed vapor of ammonia and water was driven off. By means of vessels termed the analyzer and the rectifyer, the bulk of the water was condensed at a comparatively high temperature, and run back to the generator; while the ammonia passed into a condenser, and there assumed the liquid form under the pressure produced by the heat, and the cooling action of water circulating outside. The nearly anhydrous liquid was then utilized in a refrigerator in the ordinary way, but instead of the vapor being drawn off by a pump, it was absorbed by cold water or weak liquor in a vessel called an absorber, which was in communication with the refrigerator; and the strong liquor thus formed was pumped back to the generator, and used over again. This apparatus was afterwards improved by Stanley, who introduced steam coils for causing the evaporation in the generator; and then by Pontifex & Wood, who have succeed in bringing the absorption machine to a considerable state of efficiency. Their apparatus, as applied to the cooling of liquids, consists of a generator, containing the coils, to which steam is supplied from an ordinary boiler; an analyzer, a rectifyer, and condenser; a refrigerator or cooler, in which the nearly anhydrous ammonia obtained in the condenser is allowed to evaporate; an absorber, through which weak liquor from the generator continually flows and absorbs the anhydrous vapor produced in the refrigerator; an economizer or interchanger, by means of which the cold, strong liquor from the absorber is heated by the hot, weak liquor passing from the

generator to the absorber; and pumps for forcing the strong liquor produced in the absorber back into the analyzer, where, meeting with steam from the generator, the ammonia is again driven off, the process being thus carried on continuously.

Assuming the action of the economizer to be perfect—which, of course, is a condition never met with in practice—all the heat given out by the steam in the generator coils would be found in the water issuing from the condenser, less that portion directly lost by radiation and conduction. In this case the total heat expended would be that required to vaporize the ammonia, and the water, which in the form of steam unavoidably passes off with the ammonia to the rectifyer and condenser, plus the heat lost by radiation and conduction. In the refrigerator, the liquid ammonia in becoming vaporized will take up the precise quantity of heat that was given off during its cooling and liquefaction in the condenser less the amount due to difference in pressure, and less, also, the small amount due to the difference in temperature between the vapor entering the condenser and that leaving the refrigerator. Again, when the vapor enters into solution with the weak liquor in the absorber, the heat taken up in the refrigerator is given to the cooling water, subject to slight corrections for differences of pressure and temperature. Supposing there were no losses, therefore, the heat given up by the steam in the generator, plus that taken up by the ammonia in the refrigerator, would be precisely equal to the amount taken off by the cooling water from the condenser, plus that taken off from the absorber. The sources of loss are:

Inefficiency of the economizer.

Radiation and conduction from all vessels and pipes that are above normal temperature.

Useless evaporation of water which passes into the rectifier and condenser.

Conduction of heat into all vessels and pipes that are below normal temperature.

Water passing into the refrigerator along with the liquid ammonia.

It will have been seen that the heat demanded from the steam is very much greater in the absorption system than in the compression. This is chiefly due to the fact that in the absorption system the heat of vaporization acquired in the refrigerator is rejected in the absorber, so that the whole heat of vaporization required to produce the ammonia vapor prior to condensation, has to be supplied by the steam. In the compression system the vapor passes direct from the refrigerator to the pump, and power has to be expended merely in raising the pressure and temperature to a sufficient degree for enabling liquefaction to occur at ordinary temperatures. On the other hand, a great advantage is gained in the absorption machine by using the direct heat of the steam, without first converting it into mechanical work; for in this way its latent heat of vaporization can be utilized by condensing the steam in the coils and letting it escape in the form of water. Each pound of steam passed through can thus be made to give up some 950 units of heat; while in a steam-engine using 2 lbs. of coal per indicated horse-power per hour, only about 160 units are utilized per lb. of steam without allowance for mechanical inefficiency. In the absorption machine, also, the cooling water has to take up about twice as much heat as in the compression system, owing to the ammonia being twice liquified, namely, once in the condenser and once in the absorber. It is usual to pass the cooling water first through the condenser and then through the absorber. The cost of producing clear block ice in this country, with an absorption machine of 15 tons capacity per twenty-four hours, may be taken at about 4s. per ton, with good coals at 15s. per ton, exclusive of allowance for repairs and depreciation. About 10 tons of ice can be made per ton of coal consumed, assuming an evaporative duty of 8 lbs. of water per lb. of coal.

System D.—In this, which is known as the binary absorption system, liquefaction of the refrigerating agent is brought about partly by mechanical compression, and partly by absorption; or else the refrigerating agent itself is a compound of two liquids, one of which liquefies at a comparatively low pressure, and then takes the other into solution by absorption. An apparatus of the first kind was

brought out in 1869, in Sydney, by Messrs. Mort & Nicolle, who used ammonia, with water as an absorbent. The machine consisted of an evaporator or a refrigerator, a pump, and an absorber. The evaporator was supplied with strong ammonia liquor, which was vaporized by means of the reduction of pressure induced by the pump, and so abstracted heat from the liquid to be cooled. The weak liquor passing out at the bottom of the evaporator was led by pipes to the pump, where it met with the ammonia vapor, along with which it was forced through cooling vessels under sufficient pressure to cause the solution of the ammonia, and the strong liquor thus formed was again passed into the evaporator. This machine was only used by the inventors in Australia, so far as the author is aware, and he has no particulars as to fuel consumption or cost of working. It was not likely, however, to be a very economical apparatus, because the whole of the water entering the evaporator with the ammonia had to be reduced in temperature, giving up it heat to the ammonia vapor, and to that extent preventing the performance of useful cooling work. But this disadvantage was in some degree compensated for by reducing the temperature of the strong liquor before it entered the evaporator by means of an interchanger, through which the very cold, weak liquor passed on its way to the pump.

In machines of the second kind, in which both liquids are evaporated at a low temperature, the foregoing objection does not exist, and though this mode of working has not as yet been introduced into this country, it has been successfully employed in the United States for several years by Messrs. De Motay & Rossi. The liquid used is a mixture of ordinary ether and sulphur dioxide, and has been termed ethylo sulphurous dioxide: its adoption was decided on after a series of experiments with numerous other combinations of ethers and alcohols with acids. In these investigations it was found that liquid ether at ordinary temperatures possessed an absorbing power for sulphur dioxide amounting to some 300 times its own volume; while at 60° Fahr. the tension of the vapor given off from the binary liquid was below that of the atmosphere. In working, both liquids evaporate in the refrigerator, under the influence of the pump, and in the condenser the pressure never exceeds that necessary to liquefy the ether. The compressing pump has less capacity than would be required for ether alone, but more than for pure sulphur dioxide. As to the cost of making ice by this process, the author has no particulars; but he believes it to be somewhat less than with ether. An interesting application of the binary system has lately been made by Raoul Pictet, who found that by combining carbon dioxide and sulphur dioxide he could obtain a liquid whose vapor tensions vere not only very much less than those of carbon dioxide, but were actually below those of pure sulphur dioxide at temperatures above 7° Fahr. This is a most remarkable and unlooked-for result, and may open up the way for a much greater economy in ice production than has yet been obtained. As to the results that have been obtained with this process, the author has no definite particulars; but he understands it is stated to give a production of 35 tons of ice per ton of coal.

Copper mining is largely carried on in New South Wales, the most important mines being the Great Cobar, situated 497 postal miles west of Sydney, in the center of the vast plains which lie between the Macquarie and the Bogan rivers. The ore is so rich and abundant that the industry has been a very profitable one until a very recent period, notwithstanding the great distance of the mine from the settled portion of the colony. The produce of the mine has to be hauled by wagons a distance of eighty miles to Nyngan, the nearest railway station. The industry has caused a large settlement to spring up at Cobar, and it is estimated that within a radius of three miles the population is within 3,000 and 4,000. The Great Cobar Mine gives employment to about 900 persons. The company working the mine at present experiences great difficulty in getting the copper to market. The amount of refined copper produced during the year was 4,765 tons. During the year 1884 the Great Cobar Company raised 21,561 tons of ore, and smelted 23,899 tons, yielding 2,709 tons of fine copper. At the end of the year the company had ready for smelting 1,000 tons of 10 per cent. ore, 5,000 tons 8 per cent., and 2,233 tons 5 per cent. Up to the close of 1884 the company had smelted 122,795 tons of ore, the average yield of which was 13.17 per cent. of fine copper. The greatest depth of the main shaft is 564 feet, and from that diamond drills have been sunk 60 feet further. The lode at this depth is said to show a thickness of 40 feet of fair yellow sulphide ore.

AMOUNT OF HORSE-POWER USED IN PROPELLING STREET CARS.

By AUGUSTINE W. WRIGHT.

From Proceedings of the Association of Engineering Societies.

At the present time great interest is manifested by street railway companies regarding the question of the substitution of some motive power to propel their cars other than horse-flesh. The various systems, electrical, cable, compressed air, Honigman, steam dummies, etc., etc., are prominently before the public, and each for itself claims, if not perfection, certainly that it is better than any other system.

It appears to me that great ignorance exists upon the part of inventors and street railway companies themselves as to the amount of power required to start a street car and to maintain it in motion under average conditions. The following is an attempt toward a solution of this problem. We will begin with horse-power: Watt's experiments, made with large horses of the London brewers, gave 33,000 pounds raised one foot high in one minute as the power exerted by an average horse, and this as you all know, is the allowance in figuring engine power. This is on the assumption that a horse can exert a force of 150 pounds over 20 miles per diem at the rate of 220 feet per minute, or $2\frac{1}{2}$ miles per hour during 8 hours. But the horse's power is very variable at different speeds. Tredgold's experiments gave 125 pounds; Smeaton, 100 pounds; Hatchette, 128 pounds; all 20 miles per diem at $2\frac{1}{2}$ miles per hour. Gayffier fixed the power of a strong draught horse at 143 pounds, 22 miles per diem at $2\frac{3}{4}$ miles per hour, and an ordinary horse, 121 pounds for 25 miles per diem at $2\frac{1}{2}$ miles per hour.

As the speed of a horse increases his power of draught diminishes very rapidly, until he can only move his own weight.

The following table shows the results obtained by different authors; those of Tredgold being for six hours' daily labor, and those of Wood for ten hours:

Velocity. Miles per hour.	Tests of draught according to Leslie.	Tredgold.	Wood.
2	100	166	125
3	81	125	83
4	64	83	62
5	49	42	52
6	36	—	42
7	25	—	36
8	16	—	31
9	9	—	28
10	4	—	25

From the above table, it appears that, according to Wood, at 4 miles per hour a horse can only draw half his load at 2 miles; at 8 miles, only a quarter, etc.

Sir John Macniel estimates his power at 60 lbs., moved 8 miles per diem at same velocity (Gillespie). Wood's Practical Treatise on Railroads contains an interesting chapter on horse-power. He made many experiments. He quotes an interesting memorial to the House of Commons, May 3, 1830, from the proprietors of various (33) stage coaches running out of Liverpool, employing 709 horses. These horses traveled an average distance of 13 miles daily, at a speed not exceeding 10 miles per hour, and the stock had to be renewed every *three years*.

Tredgold assigned 37 pounds as the power that a horse should exert over a distance of 10 miles in a day at a velocity of 10 miles per hour, or one hours' work. This was founded upon his experiments on stage coach horses. They endured this service only three years.

The speed of North Chicago City railway cars is 6 miles per hour, including stoppages, and the average time of service is reckoned at five years for each horse, traveling upon selected cobble stone pavement. Before the cobble stone was adopted the average railway service was four years per horse. The chief street railways of the United States estimate the railroad life of their horses at from three to five years.

May 17th, 1881, I had the honor of addressing you on "The Best Pavement

for Horse Railroad Tracks." Permit me to quote from that paper. "I recently made the following tests of the force required to start car 110 of the North Chicago City Railway Co., and to keep it in motion after it was under way, using a Fairbanks dynamometer. The track has a grade of two-tenths of a foot per hundred. (This grade is up and down, changing, say, each 250 lineal feet, and is compensated, as the observations were taken upon up and down grades.) The track was not free from sand. Between Chicago Avenue and North Avenue, on Clark, Division and Clybourn Avenues, 88 tests with an average of 14.8 passengers, weighing (estimated at 140 lbs.), with car, 6,772 lbs. The force required to keep the car in motion at an average speed of five miles per hour, including stops, averaged 109.5 lbs., or per ton, 32.3 lbs. This is on an old, worn-out iron rail. Between Chicago Avenue and Madison Street, on Clark, on new steel rail, 53 tests, with an average of 20.9 passengers, gave 59.8 lbs. as the force required to keep the car in motion. This is an average of 15.6 lbs. per ton. The car made 17 starts on this track with an average of 18.7 passengers. Average force exerted to start, 426.5 lbs. Average per ton, 116.5 lbs. On the first mentioned track, 30 tests, with an average of 18.1 passengers, gave an average force of 487 lbs.; average per ton, 134.6 lbs.

Recapitulated, the force exerted per ton was, in pounds:

On good track, to start, 116.5;
to keep in motion, 15.6.
On bad track, to start, 134.6;
to keep in motion, 32.3.

These tests indicate the great loss of power entailed by bad track, and also the great loss in starting; and the better the track the greater the relative loss in starting. On the poor track 134.6 lbs. per ton was exerted to start, and this is 4.1 times the force required to keep the car in motion. On good track 116.5 pounds was the force required to start, but this is 7.1 times the force required to keep the car in motion.

Upon the North Chicago Citry Railway the average weight of car and its load is 7,740 pounds, or in short tons, 3.87. Passengers averaged at 140 pounds. Our track is now all good. The average force, therefore, exerted in propelling one car is $3.87 \times 15.6 = 60.372$ pounds when the car is in motion, and $3.87 \times 116.5 = 450.855$ pounds force to start. The horses average 137.97 minutes service per diem. One hundred and three tests upon 17 different cars, open and close, on various lines, with different drivers, made by me on different days and hours, give the following average for the horses: Time consumed in stopping, during which no power is exerted by the horse, 13.22 minutes. Time from starting until average speed is reached, 7.88 minutes.

Now, the horses average as per above 137.97 minutes daily service.

Deducting time they are not exerting force, 13.22 minutes daily service.

Leaves actual work, 124.75 minutes daily service.

Of this power is exerted to maintain motion, 116.87 minutes daily service.

And extra power is exerted during 7.88 minutes daily service.

The horse-power, therefore, exerted in propelling a North Chicago railroad car with its average load by a team in its average day's work is:

$$\frac{450.855 \times 311.5 \times 7.88}{33.000} = 33.53 \text{ H. P.}$$

starting.

$$\frac{60.372 \times 623 \times 116.87}{33000} = 133.22 \text{ H. P.}$$

maintaining motion.

Total, 166.75 H. P.

This is used during 137.97 minutes, average per minute, 1.208 H. P. per team; or for each horse, 604 H. P.

Upon a poor track my previously quoted experiments show that this power would be about doubled, or 2.4 H. P. would be used per average car. About $\frac{1}{5}$ of the horse power is used in starting the car (20.1 per cent.). Mr. Angus Sinclair experimented upon the Third Avenue Elevated Railroad, New York, and estimated that the average pull on the draw-bar was five times greater than it would have been if the motion of the train could have been continuous. See *National Car-Builder*.

A. M. Wellington found, by his experiments, that the initial friction in starting trains of loaded cars was 5.47 times that required to keep them in motion at a speed of 10 to 15 miles per hour. See

Trans. A. S. C. E., December, 1884. Charles E. Emory, Ph. D., found 11.8 pounds per ton of 2,000 pounds to be the resistance on straight and level track in New York. This is less than my average, but his tests were probably made on a center-bearing rail, the usual rail in New York, and this we know offers less resistance to progress, as the head is comparatively clean, while the step-rail head upon which I experimented was *level with the adjoining outside pavement*, and consequently covered more or less with sand and dirt.

D. K. Clarke, in his work on tramways, states that H. P. Holt found the resistance per gross ton on straight, level track varied from 15 to 40 lbs.; Henry Hughes, 26 lbs.—often much more, occasionally less; M. Tresca, 22.4 lbs. per ton. Subsequently M. Tresca removed two flanged wheels on one side of the car, and then found the resistance 15.25 lbs. Mr. Clarke assumes 20 lbs. per ton, and says at times it is 40 lbs. per ton. "An average of 30 lbs. per ton may be taken for the calculation of the ordinary tractive force." In his second volume he states: "The average resistance (30 lbs. per ton), already in the first volume adopted for calculation, may be re-adopted, although an occasional maximum of 60 lbs. per ton may be reached, and, on the contrary, a minimum of 15 lbs. per ton when the rails are wet and clean, straight and new.

Mr. Clarke's remarks refer to grooved rails, which offer greater resistance than the step rail. General Gilmore estimates this resistance at $16\frac{2}{3}$ lbs. per short ton with track in average condition for United States. Mr. C. B. Holmes, President and Superintendent Chicago City Railway, stated that his cable railway required for ordinary operations, engines of 477 horse-power; of that it took 389 horse-power to move the cable and machinery. Eighty-eight horse-power ($18\frac{1}{2}$ per cent.) was used for the propulsion of 240 cars, weighing 6,000 lbs. each, and carrying each 5,00 lbs. of passengers. The average speed was 9 miles per hour, or 792 feet per minute. This statement would indicate that only $\frac{88}{240}$=.367 horse-power per car was required, while my experiments would give: as 3.87 (my average load) is to 5.5 (his average load), so is 1.208 horse-power (used by me) to 1.71 horse-power required.

There must have been some mistake in his test, for .367 horse-power=12.111 foot-pounds. As his speed is 792 feet per minute, the tractive force exerted would be only 15.29 pounds for 5.5 tons, a resistance of less than 3 pounds per ton (2.78 pounds), which is impossible upon a step rail.

Our fellow-member, D. J. Miller, M.E., while employed upon the above mentioned cable railway, made experiments upon the horse-power used. He found that at an average speed of 6.85 miles per hour or 602.8 feet per minute, 1 horse-power was required for each ton of cable and machinery and .2 of a horse-power for each ton of car and its passengers. For my average load of 3.87 tons, this would equal .774 horse-power, instead of 1 2 horse-power as estimated by me. Mr. Miller's .2 horse-power=6,600 foot pounds. His average speed being 602.8 feet per minute, his resistance to traction could have been only 10.95 pounds, including starting the cars. This is 3.94 times the resistance found by Mr. Holmes, but nearly 30 per cent. less than my experiments would indicate. Mr. Miller, however, *assumed* the weight of passengers, having no count of their number, and must have overestimated the load and experimented with the track unusally clean. My average of 15.6 pounds per ton, agreeing so nearly with that of M. Tresca, 15.25, as above quoted, confirms my opinion that it cannot be far wrong. While it is true that M. Tresca's experiment quoted was with only one flanged wheel upon each axle, yet that wheel traveled in a groove, and the resistance could not vary much from my two flanged wheels not in a groove. The car wheels in Chicago are 30 inches in diameter. The horses of the North Chicago Railway weigh about 1,100 lbs. each. The speed at which they travel upon the road averages 623 feet per minute or 7.08 miles per hour. Their average horse power developed being each .604 horse-power equals 19.932 foot-pounds. Divided by 623, the distance per minute, gives 31.99 lbs. tractive force. Leslie's estimate at 7 miles per hour was 25 lbs. Wood's estimate was 36 lbs., at the same speed.

Our horses work daily 2 hours 17.97 minutes, but *seven* days in the week, unless prevented by some unforeseen cause.

I have neglected extra resistance caused by curves, because our lines are chiefly tangents, and it is very difficult to measure the force exerted upon curves, for it varies greatly between 400 and 1,000 lbs., upon the dynamometer with the same car and load. My tests were so unsatisfactory upon curves that I have thought it best to omit them entirely. Then, too, the horse walks around the curve, and the lessened speed in a measure offsets the increased resistance.

The greatest exertion of force upon a tangent during my dynamometer experiments occurred in starting a loaded car. It was 1,500 lbs. average per ton 283.5 lbs. Passing through some slush, caused by snow thrown upon the track, it equaled 75.6 lbs. per ton.

In estimating for any independent motor to propel a street car upon the North Chicago Railway, I would take the maximum load and resistance. I have known of 120 passengers upon an open car. Averaging them at 140 lbs. each, equals 16,800 lbs.; car, 4,800 lbs.; total, 21,600 lbs., or 10.8 short tons. Speed in starting, 0 to 623 feet per minute; average, 311.5. $\frac{10.8 \text{ tons} \times 311.5 \text{ feet} \times 283.5 \text{ lbs.}}{33{,}000} =$ 28.9 horse-power required; a small portion of this power would be constantly employed, but it must be in reserve. With the electric or cable system no such allowance would be required, for the reason that this excess of power is only needed to *start* the car, and my experiments indicate that the car is starting only one-seventeenth of the time, while it requires no power one tenth of the time. For each 17 cars upon a line, therefore, it would be necessary to furnish power to *start one* car and to maintain sixteen cars in motion, less the power when stationary, as it is not probable, nor is it necessary, that all should start at the same instant.

During my experiments the car stopped upon an average each 1,178 lineal feet. We stop only at street intersections, or at the center of blocks more than 500 feet long.

The following returns are taken from the Sixteenth Annual Report of the Massachusetts Board of Railroad Commissioners:

Name of Railroad.	Number of horses owned.	Number of Miles Run.	Number of Passengers Carried.	Average No. of Passengers per Round Trip.
Highland	909	1,670,347	10,452,441	43
Lynn & Boston	608	1,052,296	6,364,009	50
Metropolitan	3183	6,046,879	34,574,135	38
Middlesex	601	1,047,411	7,099,892	45
South Boston	857	1,470,261	9,706,299	41
Total	6158	11,287,196	68,196,776	Average. 43.4

From the above it appears that the stable average daily distance traveled by the above horses equals 10.04 miles, found by dividing total number of miles run by total number of horses, and this by 365 and multiplying by $2 \frac{11{,}287{,}196 \times 2}{6158 \times 365} =$ 10.04.

The average number of passengers for these five railroads per round trip being 43.4 per single trip, equals 21.7. Averaging them at 140 pounds, equals 3,038 pounds. Add weight of car, 4,800 pounds equals 7,838 pounds, or 3,919 short tons, which is in excess of my average load of 3.87 tons.

It is fair to assume that these horses are worked to the best advantage and that this is all that can be expected of a horse upon a tramway.

The stables of the North Chicago Railway are located at or near one end of each line. The horses are in excellent condition. Their mileage could not be

increased, even if it was thought desirable, unless they were changed from car to car upon the road, and this would cause delay and inconvenience. They now make two round trips and could not make more without adding 50 per cent. to the distance they now travel or changing upon the road.

FLAME CONTACT—NEW DEPARTURE IN WATER HEATING.

By THOS. FLETCHER, F.C.S.

From "English Mechanic and World of Science."

It is my intention to prove to you, on theoretical grounds, and also by experimental demonstration, in such a manner as will admit of no possible doubt, that the present accepted system of water heating, by gaseous or other fuel, is a very imperfect means for an end, and is, both in theory and practice, essentially faulty. My statements may appear bold, but I come prepared to prove them in a manner which I think none of you will question, as the matter admits of the simplest demonstration. I will, in the first place, boil a specified quantity of water in a flat-bottomed vessel of copper; the time required to boil this you will be able to take for yourselves, as the result will be visible by the discharge of a strong jet of steam from the boiler. I will then take another copper boiler of the same form, but with only one-half the surface to give up its heat to the water, and will in this vessel boil the same quantity of water with the same burner in a little over one-half the time, thus about doubling the efficiency of the burner, and increasing the effective duty of the heating surface nearly fourfold, by getting almost double the work from one-half the surface. The subject is a comparatively new one, and my experiments are far from complete on all points; but they are sufficiently so to prove my case fully. As no doubt you are all aware, it is not possible to obtain flame contact with any cold, or comparatively cold, surface. This is readily proved by placing a vessel of water with a perfectly flat bottom over an atmospheric gas burner; if the eye is placed on a level with the bottom of the vessel a clear space will be seen between it and the flame. I cannot show this space on a lecture table to an audience; but I can prove its existence by pasting a paper label on the bottom of one of the boilers, and exposing this to the direct impact of a powerful burner during the time the water is being boiled, and you will see that it comes out perfectly clean and uncolored. Now, it is well known that paper becomes charred at a temperature of about 400° F., and the fact that my test paper is not charred proves that it has not been exposed to this temperature, the flame being in fact extinguished by the cooling power of the water in the vessel. I need hardly remind you that the speed with which convected or conducted heat is absorbed by any body is in direct ratio to the difference between its own temperature and that of the source of heat in absolute contact with it; and, therefore, as the source of the heat taken up by the vessel is nothing but unburnt gases, at a temperature below 400° F., the rate of absorption cannot, under any circumstances, be great, and the usual practice is to compensate for this inefficiency by an enormous extension of surface in contact with the water, which extension I will prove to you is quite unnecessary. You will see I have here a copper vessel with a number of solid copper rods depending from the lower surface; each rod passes through into the water space and is flattened into a broad head, which gives up its heat rapidly to the water. My theory can be stated in a few words: "The lower ends of the rods, not being in close communication with the water, can, and do attain a temperature sufficiently high to admit of direct flame contact, and as their efficiency, like that of the water surface, depends on the difference between their own temperature and that of the source of heat in absolute

contact with them, we must, if my theory is correct, obtain a far greater duty from them. I do not wish you to take anything for granted; and although the surface of the rods, being vertical, can only be calculated for evaporating power at one-half that of a horizontal surface, as is usual in boiler practice, my margin of increased duty is so great that I can afford to ignore this, and to take the whole at what its value would be as horizontal surface, and still obtain a duty 50 per cent. greater from a surface which is the same in area as the flat-bottomed vessel on the fireside, but having only one-third the surface area in contact with the water. I do not, of course, profess to obtain more heat from the fuel than it contains, but simply to utilise that heat to the fullest possible extent by the use of heating surfaces beyond comparison smaller than what have been considered necessary, and to prove not only that the heating surface can be concentrated in a very small area, but also that its efficiency can be greatly increased by preventing close water contact, and so permitting combustion in complete contact with a part of the heating surface. I will now boil 40 oz. of water in this flat-bottomed copper vessel, and, as you will see, sharp boiling begins in three minutes fifteen seconds from the time the gas is lighted. The small quantity of steam evolved before this time is of no importance, being caused partly by the air driven off from the water and partly from local boiling at the edges of the vessel owing to imperfect circulation. On the bottom of this vessel is pasted a paper label, which you will see is untouched by the flame owing to the fact that no flame can exist in contact with a cold surface. It may be thought that, owing to the rapid conducting power of copper, the paper cannot get hot enough to char. This is quite a mistake, as I will show you by a very curious experiment. I will hold a small plate of copper in the flame for a few seconds, and will then hold it against the paper. You will see that, although the copper must of necessity be at a temperature not exceeding that of the flame, it readily chars the paper. We can, by a modification of this experiment, measure the depth of the flameless space, as the copper, if placed against the paper before it has time to be previously heated, will, if not thicker than 1-40 inch, never become hot enough to discolor the paper, showing that the flame and source of heat must be below the level of a plate of metal this thickness. In repeating this experiment I must caution you to use flour paste, not gum, which is liable to swell and force the paper past the limit of the flameless space, and also to allow the paste to dry before applying the flame, as the steam formed by the wet paste is liable also to lift the paper away and force it into the flame. I will now take this vessel, which has only one-half the surface in contact with the water, the lower part being covered with copper rods, 3-16 in. diameter, ½ in. centers apart and 1½ in. long, and you will see that with the same burner as before, under precisely the same conditions, sharp boiling takes place in 1 minute 50 seconds, being only 13 seconds more than half the time required to produce the same result with the same quantity of water as in the previous experiment. Although the water surface in contact with the source of heat is only one-half that of the first vessel and the burner is the same, we can see the difference not only in the time required to boil the 40 oz. of water, but also in the much greater force and volume of steam evolved when boiling does occur. With reference to the form and proportions of the conducting rods, these can only be obtained by direct experiment in each case for each distinct purpose. The conducting power of a metallic rod is limited, and the higher the temperature of the source of heat, the shorter will the rods need to be, so as to insure the free ends being below a red heat, and so prevent oxidation and wasting. There are also other reasons which limit the proportions of the rods, such as liability to choke with dirt and difficulty of cleaning, and also risk of mechanical injury in such cases as ordinary kettles or pans—all these requirements need to be met by different forms and strengths of rods to insure permanent service, and, as you will see further on, by substituting in some cases a different form and type of heat conductor. To prove my theory as to the greater efficiency of the surface of the rods in contact with the flame as against that in direct contact with the water, I have an-

other smaller vessel which, including the rods, has the same total surface in contact with the flame, but only one-third the water surface as compared with the first experiment. Using again the same quantity of water and the same burner, we get sharp boiling in 2 minutes 10 seconds, being an increase of duty of 50 per cent., with the same surface exposed to the flame. The rods in the last experiment form two-thirds of the total heating surface, and if we take, as I think for some careful experiments we may safely do, one-half the length of the rods to be at a temperature which will admit of direct flame contact, we have here the extraordinary result that flame contact with one-third of the heating surface increases the total fuel duty on a limited area 50 per cent. This really means that the area in contact with the flame is something like six times as efficient as the other. In laboratory experiments it is necessary not only to get your result, but to prove your result is correct, and the proof of the theory admits of ready demonstration in your own laboratories, although it is unfit for a lecture experiment, at all events in the only form I have tested it. If you will take two ordinary metal ladles for melting lead, cover the lower part of one of these with the projecting rods or studs and leave the other plain, you will find on melting a specified quantity of metal in each that the difference in duty between the two is very small. The slight increase may be fully accounted for by the difference in the available heating surface reducing the amount of waste heat passing away, and this proves that flame contact, and therefore quick absorption of heat, takes place on plain surfaces as soon as these are above a certain temperature which, in a metal ladle, very soon occurs. What the temperature is which admits of flame contact I have, as yet, not been able to test thoroughly, and it will need some consideration how the determination of this is to be correctly made; at the same time it is a question in physics which should be capable of being answered. Let us now take the other side of the question. If the efficiency of a surface depends on flame contact, there must of course be flame, or at least gases of an extremely high temperature, and we therefore cannot expect this extraordinary increase of efficiency in any part of our boiler except where flame exists, and if these projections are placed in a boiler, anywhere except in contact with flame, their efficiency must be reduced to that of ordinary heating surface. They are, of course, useful, but only in the same way as ordinary flue surface. When we come to boilers for raising steam, which have to stand high pressures, we come to other difficulties of a very serious nature, which require special provision to overcome them. To put such rods as I have referred to in a boiler-plate necessitates the plate being drilled all over with holes, causing a dangerous source of weakness, as the rods cannot be used as stays; further than this, they would render really efficient examination a matter of extreme difficulty, and would be liable to give rise to frequent and almost incurable leakages; but there is, fortunately, a very simple way to overcome this difficulty. I have found that rods or points, such as I have described, are not necessary, and that the same results can be obtained by webs or angle-ribs rolled in the plates. My experiments in this direction are not complete, and at present they tend to the conclusion that circular webs, which would be of the greatest efficiency in strengthening the flues, are not so efficient for heating as webs running lengthways with the flue, and in a line with the direction of the flame. This point is one which I am at present engaged in testing with experimental boilers of the Cornish and Lancashire type, and, as we have in gas a fuel which renders every assistance to the experiment, it will not take long to prove the comparative results obtained by the two different forms of web. Those of you who have steam boilers will, no doubt, know the great liability to cracking at the rivet holes in those parts where the plates are double; this cracking, so far as my own limited experience goes, being usually, if not always, on the fire side, where the end of the plate is not in direct contact with the water, where it is, in fact, under the conditions of one of the proposed webs. I think we may safely come to the conclusion that this cracking is caused by the great comparative expansion and contraction of the edge of the plate in contact with

the fire, and it will probably be found that if the plates are covered with webs, the whole of the surface of the plates will be kept at a higher and more uniform temperature, and the tendency to crack at the rivet-holes will be reduced. This is a question not entirely of theory, but needs to be tested in actual practice. There is another point of importance in boilers of the locomotive class, and those in which a very high temperature is kept in the fire-box, and this is the necessity of determining by direct experiment the speed with which heat can safely be conducted to the water without causing the evolution of steam to be so rapid as to prevent the water remaining in contact with the plates, and also whether the steam will or will not carry mechanically with it so much water as to make it objectionably wet, and cause priming and loss of work by water being carried into the cylinders. I have observed, in the open boilers I use, that when sufficient heat is applied to evaporate one cubic foot of water per hour from one square foot of boiler surface, the bulk of the water in the vessel is about doubled, and that the water holds permanently in suspension a bulk of steam equal to itself. I have, as yet, not had sufficient experience to say anything positively as to the formation or adhesion of scale on such surfaces as I refer to, but the whole of my experimental boilers have, up to the present, remained bright and clean on the water surface, being distinctly cleaner than the boiler used with ordinary flat surfaces. It is, I believe, generally acknowledged that quick heating and rapid circulation prevent, to some extent, the formation of hard scale, and this is in perfect accord with the results of my experiments. The experiment which I have shown you, I think, demonstrate beyond all question that the steaming power of boilers in limited spaces, such as our sea-going ships, can be greatly increased; and when we consider how valuable space is on board ship, the matter is one worthy of serious study and experiment. It may be well to mention that some applications of this theory are already patented. I will now show you as a matter of interest in the application of coal gas as a fuel, how quickly a small quantity of water can be boiled by a kettle constructed on the principle I have described, and to make the experiment a practical one I will use a heavy and strongly-made copper kettle which weighs 6½ lbs., and will hold when full one gallon. In this kettle I will boil a pint of water, and, as you see, rapid boiling takes place in 50 seconds. The same result could be attained in a light and specially made kettle in 30 seconds, but the experiment would not be a fair practical one, as the vessel used would not be fit for hard daily service, and I have therefore limited myself to what can be done in actual daily work rather than laboratory results, which, however interesting they may be, would not be a fair example of the apparatus in actual use at present.

CHOLERA IN ITS RELATION TO WATER SUPPLY.

By GEORGE HIGGIN.

From "Nature."

The epidemic of Asiatic cholera, which has been raging in Spain during the last two years, and which appears even yet to be lurking in some portions of that peninsula, has furnished some interesting data as regards its connection with water supply, to which it would be wise in us to direct our attention, not only from the interesting nature of the facts as such, but also because it is not improbable that ere the disease quits Europe it may visit our own shores.

Broadly speaking, it would appear that in Spain this formidable disease never became truly epidemic or dangerous in any city in which there was a pure and good supply of water, and proper means were taken to guard against the sources being polluted by any of the specific choleraic poison.

In support of this idea I would desire to call attention to the cities of Toledo, Seville, Malaga, and Madrid, in contradistinction to such places as Aranjuez, Saragossa, Granada, and Valencia. I will commence with Madrid. This city, whose population at the last census was 397,816, suffered very severely, indeed, under the last epidemic of 1865, when during several days immediately following a very severe thunderstorm, the number of cases varied from 800 to 1,200 per day. The first invasion of last year took place in Madrid on May 20, and the disease ran its course during the whole of the summer, gradually disappearing towards the end of the month of September. The total number of cases during the whole of the period was 2,207, and the deaths 1,366. The total number of cases, therefore, during the five months that the disease never abandoned the city was barely more than what occurred during two days only of the epidemic of 1865, being little more than ½ per cent. of the population. I think, therefore, we may safely say that the disease never assumed a truly epidemic form. The greatest number of cases, as was to be expected, took place during the months of July and August; the first notable increase took place on July 25, and the first notable decrease on August 13.

In connection with this it is interesting to note that Madrid was subject to severe thunderstorms during the latter end of July, and that 119 millimeters of rain fell during the month. These storms began on the 13th, and were especially severe on the 23d, 24th, 26th, 27th, and 31st, the first notable rise in the cases of cholera occurring between the 25th and 28th. As a general rule, no rain falls in Madrid in July, and the occurrence of these severe thunderstorms and heavy falls of rain was quite phenomenal.

The new water supply from the Guadarama Mountains was completed shortly before 1865, and the greater part of the drainage was also finished; but at that time the new water supply had scarcely come into use, the large majority of the houses being supplied from the old fountains which existed in various parts of the city. During the last twenty years the use of the Lozoya water has become very general, and an ample supply has been provided for washing the streets and flushing the sewers.

Madrid is now well drained; the sewers are built upon the Paris model, and are not what an English engineer would consider as a good type for self-cleansing purposes, but the fall is, in almost every case, very great, and it is not probable that there can be any collection of fœcal matter at any point. The connection of the street gullies with the main sewers is made without any trap, and good ventilation is thus provided. As regards the outfall of these sewers, nothing satisfactory can be said. The mouths of the main sewers, which are seven in number, all discharge on the southern side, between the station of the Saragossa Railway and that of the Northern.

The question of the proper disposal of the sewage in Madrid, as in London, has never been decided, and pending this decision the sewers were completed only as far as the outlying houses of the city, and the sewage was then allowed to find its way down to the Manzanares, in the best way it could. During the time the question has been awaiting a solution the town has extended, and houses have been built along the course of these open sewers. As might have been expected, the first serious outbreak of cholera occurred about these spots, the original germ of the disease having been imported from the neighborhood of Valencia, where the cholera was then raging.

The existence of the disease having been established beyond doubt, one of the first acts of the Municipality was to attend to the water supply. There existed 11 ancient sources, which supplied 85 taps or fountains, 22 of which were public ones, at which water-carriers were allowed to fill their barrels, and the remaining 63 belonged to groups of houses. In spite of the excellent supply brought in from the Lozoya, these old sources were still a good deal used by the inhabitants—many, from old habits, preferring to use the same water which their fathers had used, many not being willing to incur the expense of laying on the new supply. In view of the impossibility of effectually guarding against the possible contamination of so many sources of supply, the Municipality, by decree, on June 18, closed all the old ones, with the ex-

ception of that of La Fuente de la Reina, which supplied five public fountains and four private ones. The Central Government undertook the custody of the Lozoya aqueduct, the Municipality took charge of the Fuente de la Reina. The Lozoya water is drawn from the sources of the River Lozoya in the Guadarama Mountains, some 50 miles to the north of Madrid.

The river takes its rise in the granite formation; the water is excellent, and from the uninhabited condition of the country through which the river flows before the intake, it is not exposed to direct contamination from any specific poison. From the intake to Madrid the water is conducted by a series of magnificent works, partly covered, partly uncovered, to Madrid, where it is received in covered reservoirs before being distributed in the city; the service is continuous, no cisterns being used. During the whole time of the existence of cholera in the city the uncovered portion of the aqueduct was patroled by armed guards, no one being permitted to approach without a special order.

Accompanying the extensive report of Madrid, Don Alberto Bosch, amongst other plates, is an excellent map of the city, showing, by a red dot, the situation of every case of cholera that occurred; they are seen pretty thickly scattered about the uncovered exits of the sewers, and on both sides of the River Manzanares, which is, in fact, in summer, an open sewer, and in the lower portion of the city overlooking the river, and there is scarcely any part of the town where a dot is not to be found; but, with the exception of the points mentioned, the cases occurring in the remainder of the town seem to be all isolated ones; in extremely few cases do two dots occur together, showing that the disease was more of a sporadic than of an epidemic character.

Now let us take the case of Toledo. This ancient capital of Spain is certainly not a city that could be taken as a model of sanitary arrangements; on the contrary, it seem to be admirably adapted to form a good nest for any wandering epidemic, and yet, although the cholera entered it in the summer of 1884, and did not finally leave it till the autumn of 1885, the total number of cases, according to official returns, did not exceed 200, of which about one-half were fatal. The population of Toledo is over 20,000, so that the percentage of choleraic disease was only about 1 per cent. of the population for the two seasons.

Toledo was supplied with water from the river Tagus, which flows round the city, the water being lifted by pumps. Above Toledo on the same river, is situated Aranjuez, and above Aranjuez again, on the Manzanares, which is a feeder of the Tagus, is situated Madrid, in both of which towns the cholera existed in 1885, being unusually severe in Aranjuez. The Governor of the province, recognizing the suspicious character of the water, stopped the pumps, and obliged the inhabitants to send for their drinking water to a distant spring; he even forbade anyone to bathe or wash clothes in the river. The measure was a strong one, but it saved the city.

Let us next take Seville. Seville is an important city, the third in rank in Spain; it contains, according to the census of 1877, 134,318 inhabitants; it has, strictly speaking no drainage; a few ancient sewers exist for carrying off the rainwater from the lower portion of the city, but sewerage for houses does not exist. The sewage goes into cesspools, which are, in most cases, situated just outside the house, and under the street; the inhabitants are extremely cleanly in their habits, and the outsides of their dwellings are constantly whitewashed, but it is not a healthy city—typhoid fever is endemic, and the death rate rises in some parishes to 35 per mil.

Seville is situated on the river Guadalquiver, of which the rivers Darro and Genil, that flow through Granada, are feeders; as regards its water-supply, one suburb of the city, called Triana, containing about 30,000 inhabitants, is situated on the western side of the river. This portion is almost entirely inhabited by the poorer, class, and they drink generally the water of the river.

The rest of the town is supplied from an ancient Roman or Moorish aqueduct, the water being brought from an underground spring near the town of Alcala, about nine miles to the east of Seville; this water is carried by a tunnel about two miles in length under the town of Alcala; it is then carried in a covered conduit to

within a short distance of Seville, and from thence by an aqueduct made by the old Moors. The water is excellent.

An English company has quite lately erected engines at Alcala, by means of which they pump up to a covered reservoir above the town, the water from two other springs, situated also at Alcala, but on the opposite side of the river Guadaira, which flows past the town. This water is carried from the reservoir into the town by iron pipes, and distributed under considerable pressure; in character it is pure and excellent; the springs rise from the base of the sandstone at a short distance from the engine house, and are carried across the river by an iron pipe. The cholera broke out in Granada on July 14, 1885, but already on June 14 of the same year the authorities of Seville, by way of prevision, had prohibited the use of any water from the river, either for dietetic or other purposes; had authorized the English company to lay a temporary pipe across the bridge which connected the city with the Triana suburb, and had opened a number of free taps from which the inhabitants of this suburb could draw the new water.

The old Moorish supply was scarcely susceptible of contamination, as the conduit was covered for the greater part of way, and where it ran over the aqueduct no one but the Municipal guards had ever been allowed to pass; guards, however were stationed day and night on the springs from which the English company derived their water, and no one was allowed to approach them without permission.

The cholera raged fearfully in Granada during the months of July, August, and September; it descended the River Genil, which runs through Granada, and attacked the towns of Herera, Ecija, and others in the province of Seville. It broke out also at Cordova and other towns on the Guadalquivir, of which the Genil is an affluent, and it broke out in Palma, Utrera, Puerto Real, Puerto Santa Maria, and Cadiz, forming a circle around Seville, but the city itself escaped almost completely. Towards the end of September nine cases occurred in one quarter of the city, of which seven were fatal, but the disease did not spread; none of the five houses in which these cases occurred were connected on to the water supply, and it is possible they may have used well or river water, although this is not known. Jerez, which lies about half-way between Seville and Cadiz, and close to the town of Puerto Santa Maria, which was attacked by cholera, escaped also from the disease. This town possesses a very excellent water-supply, brought down some few years ago from a spring in the mountains by a native company, at a cost of £300,000.

Malaga has a population of 115,882. This city is in even a worse sanitary condition than Seville as regards its drainage, and a great deal worse as regards its cleanliness. In the old portion of the town the streets are narrow, unventilated, and intolerably filthy; the climate in summer is almost tropical.

It is difficult to obtain reliable data as to the cases of cholera in Malaga, as attempts were made to prove that no real cholera existed in Malaga; but there can be no doubt but that from June to September the cholera did exist, and it is probable that during the whole of the summer there occurred some 200 or 300 real cases of Asiatic cholera. But the disease never became epidemic, although, to all appearances the city offered a most excellent medium for the propagation of the disease, and on all former visitations had suffered very severely. But Malaga, during the last few years, has been provided with an excellent water-supply drawn from some springs situated at Torremolinas, on the coast to the westward of the city, and piped from thence into the city; and although the precautions adopted were not so complete as those at Seville, yet a more or less successful attempt was made to prevent the use of any other water than that brought from Torremolinas.

We have now examined the case of the few towns in Spain that possess a pure supply of water drawn from springs not liable to any specific contamination, and we have seen that in all cases where such a supply existed, the cholera, although present in all of them, never made any headway, or became truly epidemic, although in every case, except that of Madrid, there was no proper drainage, and the sanitary conditions were in many cases as bad as they could be.

Let us now look on the other side of the picture. We will commence with Granada—population 76,005. As regards its sanitary arrangements, this city is on a par with Malaga; about one-tenth of the town is drained, but the sewers are of a very inferior class. The city is supplied with water by canals derived from the Genil and Darro, the two rivers which serve to irrigate the magnificent plain which speads around it. A small portion is supplied from a spring called La Fuente Grande de Alfacar. The canals are uncovered and exposed to all kinds of contamination.

Through the streets the water is conducted in earthenware pipes, after the style of the Moors; many of the pipes are the original ones put down by these people before the conquest of the city by Ferdinand and Isabella. The cholera broke out about the middle of July. It is supposed to have first been brought in by some laborers who had arrived from Murcia, where the cholera was raging. It spread with frightful rapidity, and by the middle of August the official number of cases reported was over 450 per day. It died out, or rather wore itself out, about the middle of September. The total official returns give a total of 6,471 cases, and 5,093 deaths, but in the city itself these returns are said to be much under-estimated; some, indeed, say the numbers should be doubled.

No attempt was made, as was done at Toledo with such excellent results, to suppress the old water supply, and the epidemic took in a short time such alarming proportions that the local authorities were completely paralyzed. It was difficult to carry on the interment of the bodies, and at one time from 400 to 500 corpses were lying piled up in the cemetery awaiting interment.

The course of the cholera may be followed down the rivers Darro and Genil, the infected waters carrying death wherever they were used for drinking purpurposes.

Murcia — population 91,805 — from which the cholera was imported into Granada, suffered heavily also. It was carried into the plains of Murcia by the waters of the river Segura, from the baths of Archena, and it was imported into Archena by some invalid soldiers who were sent to the baths from the infected district around Valencia. The plain of Murcia is irrigated by the waters of the Segura, and the disease commenced in this district with the death of a laborer who had drunk the water of one of the irrigation channels. The inhabitants of Murcia and of the plain use principally water from the irrigation canals or from the river; this water is usually stored in large jars similar to those which held Ali Baba and his forty thieves, and among well-to-do people it is customary to keep a year's supply in hand; that is to say, the water is allowed to repose for one year, before use, in a reservoir or "algibe," constructed on purpose, or in some of these large jars sunk up to their necks in the ground; by this means it becomes perfectly clear, cool, and palatable. The poorer classes are, as a matter of course, not able to take these precautions, and have to drink the water from the canals, or after a few days' repose only.

The epidemic raged principally amongst the little cottages scattered thickly over the plain, or garden, as it is called, but the disease never developed itself in Murcia as it did in Granada, and the city itself escaped better than might have been expected. May this not be attributed to the fact that the greater part of the people in the city were drinking water collected in the foregoing year, before the cholera had appeared on the sources of their water supply? And if this be so, may we not anticipate a fresh outbreak this year, if the choleraic poison or germs are capable of outliving a year's repose and darkness?

In reference to water supply and cholera, no case is so instructive as that of Valencia. This city is fairly well drained, as drainage goes in Spain, and as regards cleanliness is certainly in a better situation than Malaga or Granada. The water supply is derived from the river Turia; it is taken from the river near the town of Manises, abut three miles and a-half above Valencia; it is passed through sand filters situated between Manises and Mislata, and is stored in a covered reservoir, from whence it is conducted by iron pipes, a distance of about one mile and a-half into the city.

In one of the interesting letters written by the special correspondent of the *Times* during his tour of inspection of

the cholera districts, a very clear description is given of the track taken by the cholera from its starting point in Alicante, where it had broken out at the latter end of 1884, to Valencia in 1885. During the course of the year 1884, the disease had crossed the frontier of the provinces of Alicante and Valencia, and established itself in Jativa, a somewhat important town, situated on one of the affluents of the Jucar—this and the Turia being the two rivers whose waters are used for the irrigation of the wonderful "Huerta," or Garden of Valencia. During the winter the disease lay dormant, but it broke out in the spring of 1885, and traveled rapidly down the river to Alcira, attacking the various towns situated on the river itself, or on the canals derived from it.

The epidemic was severe at Alcira, but, as the *Times* correspondent suggestively remarked, it ceased so soon as the inhabitants gave up drinking river water, and took their supply from a spring situated at a considerable distance from the town. From Alcira it traveled across the network of canals till it reached the river Turia. The *Times* correspondent says: "It came very near Valencia, and yet never touched the capital till it had worked right around."

At last, in the middle of May, having crossed the water supply of the city and thoroughly infected the river, it attacked the city right royally, and by the end of June the number of cases had risen to 700 daily, out of a population of 143,861. The disease died out in September, having, according to the official accounts, attacked during the four months 4,234 people.

We will now turn to Saragossa. Saragossa, the capital of the ancient kingdom of Aragon, is situated on the right bank of the river Ebro; it contains 84,575 inhabitants, and is an important city. Like most Spanish towns and cities it has no sewers; fœcal matter is collected, as in Seville, in cesspools, which are periodically emptied.

Its principal water supply is derived from the Canal de Aragon, which in its turn draws its supply from the Ebro, near Tudela. This canal was intended principally for navigation, and is now used for this purpose, and also for irrigation. It passes at a short distance above Saragossa, and the town supply, after being drawn from the canal, is stored in reservoirs, and, after depositing its mud, is then passed through charcoal filters. Some of the inhabitants of the city drank the water from an irrigation canal taken from the river Jalon; some used the waters of the Ebro, which flows close past the old walls of the city.

The disease broke out in Saragossa shortly after the middle of July, and the number of cases during the time the epidemic raged was close upon 10,000. The proportion of deaths was small, thanks to the heroic and energetic conduct of the authorities and the people. Some time before the commencement of the disease in the city, a number of small towns on the banks of the Ebro and the Jalon had been attacked by the cholera; there was therefore ample opportunity for the infection of the water-supply. Against such contamination, the only protective measure as regards the general supply was the filtration through charcoal; as regards the Jalon water, there was no protection. This source of supply was, however, ultimately stopped by the authorities, who prevented the water reaching the city, with a notable result as regarded the decrease of the epidemic in the quarter served by them.

It would be interesting to follow out still further the line of inquiry I have adopted, but the examination would be too prolix for the present purpose. The cases I have presented are typical ones; they might be increased *ad libitum*, but I think they are sufficient for my purpose. From an examination of them it would appear as though, in the case of cholera, drainage and sewerage is a secondary subject, the primary one being the water supply. We have seen that the cities of Toledo, Seville, and Malaga, although in bad conditions as regards their sewerage and general sanitary arrangements, yet escaped from any serious attack of cholera, whilst Murcia, Valencia and Saragossa suffered most severely, although in their case the sanitary arrangements were certainly not worse, but if anything better, than the three former cities. But, in the case of the three first-named cities, each one enjoyed a supply of water drawn from springs situated at a distance from the city, and carefully watched and guarded

to prevent any contamination, and the exclusive use of this water was rendered imperative by the authorities.

In the case of Valencia, Saragossa and Murcia, we have a supply drawn from rivers subject to contamination from various sources, against which the only protection was that furnished by the doubtful process of filtration.

There can be no doubt that the cholera attacks in preference those who live under unsanitary conditions, and whose habit of body is by this means prepared to receive the germs of any disease that may be prevalent.

There is no doubt that the virus can be conveyed about from one place to another, like small-pox, typhus, and various other diseases, either by clothes or in the human body, and where it finds a proper medium it will develop itself and extend; but, like these other diseases, it can in these conditions be isolated, fought, and conquered, but without doubt the medium *par excellence* for the spread of cholera-poison is water, and more particularly so when water so infected is used for dietetic purposes.

When it gets possession of the water supply of a city, no bounds can restrain it; there is but one resource, and that is the cutting off of the water.

We do not yet know in what the choleraic poison consists; it is, in all probability, a a micro-organism of some sort which is capable of very rapid development in water, but it cannot be yet said what is the particular micro-organism which produces cholera. The "comma Bacillus," of Koch, has not been accepted by the scientific authorities; on the contrary, very high ones deny altogether its identity with cholera, and assert that it is to be found in the mouth of every healthy person. Whatever the specific germ may be, it is at least doubtful whether any filtration will intercept it; from the experience obtained at Valencia and Saragossa it appears evident that neither sand nor charcoal will do so.

In a paper read recently at the Institute of Civil Engineers, Dr. Percy Frankland asserts that the London Water Companies do, at the present moment, eliminate 96 per cent. of all the micro-organisms in the Thames water by simple filtration through 3 feet of fine sand. This may be so, but it is equally certain that filtration through sand, even at a slow speed indeed, will not eliminate the minute particles suspended in waters of a deltaic character, and which gives such water their peculiar color. If sand is incapable of intercepting these particles, it may also be incapable of intercepting the specific germs or poison that produce cholera in the human body.

Filtration is, at the best, but a doubtful proceeding for the purification of water. It is impossible to control effectually the speed of the filters; they vary at every moment, and although a mean term may be arrived at by taking the area of the filter-beds and the volume of water filtered in the twenty-four hours, yet this really affords no reliable guide as to the actual speed at which the water has passed the filters. It is probable, nay, almost certain, that out of a given quantity of water, no two gallons have passed at the same speed, and it is possible and probable that one-half of the total volume may have passed the filter at double or treble the speed of the rest.

To insure immunity from contamination, the only real and practical method appears to be that of capturing the water at a pure source and conducting and delivering it in such a way as to render it impossible that any specific germ or poison should have obtained access to it. In the matter of cholera, for instance, with the experience of Valencia and Saragossa before us, one cannot feel any confidence in water which is taken from a river liable to so many sources of contamination as is the Thames, and it is at least doubtful whether any system of filtration would be capable of eliminating cholera-poison from such waters. It is extremely probable that simple filtration through sand will not do it.

The very interesting series of letters published by the *Times* on the subject of cholera in Spain, afford much valuable data as to the causes of the disease, or rather as to its mode of propagation. It is unfortunate that the writer seems to have gone out with a preconceived idea that the cause of the propagation of cholera was defective drainage, and consequently to have devoted the greater part of his time to the examination of the sewerage of the various towns he visited, and of their general sanitary arrangements, the water supply being as a

rule relegated to the second place. He appears to be a strong advocate for traps, and not to be aware that the best sanitary authorities of the present day are beginning to doubt very strongly the utility of traps, and to rest their practice rather on the thorough ventilation of sewers, the rapid discharge of their contents, and a complete disconnection between the house drainage and the main sewers.

It is not too late for some scientific investigator to go over the track of the cholera invasion in Spain, to trace the progress of the disease in the towns it visited, and ascertain all the facts connected with their drainage and water supply, and also, what is not less important, examine the conditions of those towns which so far have enjoyed a practical immunity from the epidemic. As much is to be learned from this negative evidence as from the other.

Pending the discovery by scientific men as to the particular germ or poison that creates cholera, such a practical examination as I suggest would be of immense value to us by teaching how the propagation of the disease is principally brought about, and what are the best means of preventing it.

ENGINEERING—ITS ACHIEVEMENTS AND ITS REWARD.

By C. W. BUCHHOLZ.

Proceedings of the Engineers' Club of Philadelphia.

Professor Reuleux read, about a year ago, before the Gewerbe Verein, in Vienna, a very interesting paper, entitled: "Kultur und Technik," of the beginning of which the following is almost a literal translation. He says:

"In taking a broad view over the present condition of culture in this world of ours, we cannot fail to see what an all important influence is exerted by technical skill based upon scientific principles, and as practised in our days. No one can ignore how it has helped us to accomplish incomparably more material progress than was possible to mankind a few hundred years ago—be it in the domain of rapid transportation of passengers, or of heavy cargoes by land or sea; be it in the tunneling of great mountains, in the boring of deep mines, or in the ascending high in the air; be it in sending with lightning rapidity our thoughts around the earth, or in transmitting our voice for hundreds of miles across the country; be it on the one hand to control the mightiest forces and to compel them to do us mechanical service, or be it to utilize, on the other hand, the most subtle processes of nature, elements of the material world so delicate and fine that they almost escape ordinary observation.

"Everywhere in our modern life, here, around us, upon us, with us, and near us, wherever we go, technical science has become our busy servant and companion, in ever restless activity, the influence of which we never really appreciate until we have to do without its assistance for ever so short a period. All this is well known, and has become almost commonplace, yet it appears to me that it is not so thoroughly established as it should be among educated people, and not even in the narrower circles of men of technical training.

"The world does not as yet look upon technical science by any means as the great lever and factor of culture, which it really is."

The Professor then goes on to hint at the probable cause why this is so, but he does not advance any definite reasons, and he refuses to deliver a panegyric on "Technic," or "Engineering," as I will call it hereafter, for the latter nowadays embraces nearly all the first implies; and he declines to demolish by his facts and logic those who refuse to give to the arts and sciences the long-hoped-for acknowledgment. He, however, very ably proves and shows what the true position of engineering is in the universal activity towards the solution of the great prob

lem of culture, and he very clearly points to the methods it has ever pursued since the earliest times.

Now, I would like more particularly to draw the attention of the Club to the very question the Professor leaves unanswered, but which seems to me to be of the greatest importance to every man of mechanical training, to every engineer who has selected his profession, not in order to maintain a precarious and humble existence, but rather to rise above his fellowmen and become a distinguished member of society; a leader of progress as well as the pioneer, corresponding to his higher education and to his responsible and arduous duties. Why is it that in every highly civilized community the men graduating from the classical departments of universities generally at once take a higher social position than those coming from polytechnic schools? Why is not the degree of Doctor conferred upon the engineer as well as upon the lawyer, the physician, and the preacher? Why is it that all other professions have far outstripped him in their social and political influence? Surely the engineer has done much more for the general development of the resources of our mother earth and for the progress of mankind, and has accomplished much more towards making "life worth living" than any other profession, be it ever so classical or learned in the laws, in medicine, or theology.

Leaving out of consideration the temples and palaces, and public buildings erected during the very earliest periods of recorded history in Eastern and Central Asia, whose people, although rich in poetry and culture, have remained stationary in technical knowledge for many centuries, ignoring pre-historic peoples and their monuments, and beginning our review with the nations bordering on the Mediterranean, we find there the birthplace of the engineer, the architect, the astronomer, and the mathematician. Nearly all the records of primitive times chronicle little else but deeds of heroism during everlasting wars between different tribes and nations, and it is to be presumed that the first employment for the engineer must have been with their armies, making roads and building crude fortifications. Mechanics and craftsmen of all kinds were very scarce, and it is no wonder, as Homer tells us, that the great Ulysses himself, the hero and chief of a nation, had to construct with his own hands the ships he sailed in, and had to design and execute in person the decorations of his palace. But as the savage spirit of perpetual war somewhat subsided, and as commerce increased, and as navigation began to be better understood, it soon became necessary to improve the natural shelter of harbors by artificial means; and to the Phœnicians, probably, belongs the credit of employing the first civil engineer to construct the celebrated and ancient harbors of Sidon and Tyre. This enterprising people, as long ago as 1280 years before our era, passed the Straits of Gibraltar in their ships, and founded the port of Cadiz, where they erected docks and large warehouses to accommodate the goods of the then known world.

Egypt, another country of the greatest antiquity, deserves, undoubtedly, the credit of being the cradle of all science, and of nursing it with the greatest care. Greece drew all her knowledge from there, and it must be admitted that a great amount of modern engineering skill had its origin on the banks of the Nile; 2,300 years B. C. a king of Egypt changed the course of the Nile from the foot of the sandy mountain on one side through the center of its valley, by constructing new and deep channels and several canals. By this simple method he reclaimed thousands of acres of marshes, raised the surrounding lowlands by filling with the material excavated, until it was above the annual inundations of the river, and thereby enabled his successor to build large cities with safety upon sites thus raised above the floods. Each successive monarch improved and continued the construction of canals and storage lakes, until the whole valley of the Nile became the most fertile and prosperous country on the face of the earth, and 4,000 years of misrule and fanaticism have been unable to this day to destroy the results achieved by the system of drainage and irrigation as founded by King Mines and his engineers. The construction of the pyramids, obelisks, sepulchres, and magnificent temples, especially those of Isis and Serapis, together with other innumerable monuments of antiquity, was per-

haps the joint effort of the engineer and architect, although it is most likely in those early times the two professions were not divided as they are to-day, and they are still depending more or less upon each other for success.

The inscriptions upon nearly all these proud remains of ancient skill show conclusively that the chisel, the mallet, and nearly all the tools as used in our present time for the quarrying and dressing of stone were known to the old Egyptians, and it is marvelous to contemplate how thoroughly the principles of the lever must have been understood by them, in order to move for many miles from the distant quarries, and raise to great heights, the enormous masses of stone used in their construction.

The great development and the high cultivation of the sciences and arts rapidly increased a taste for luxury and ease, and naturally destroyed the warlike spirit of the people of Egypt. They were in turn conquered and oppressed by the Greeks and the Romans, but the material progress founded by their engineers upon the laws of nature, then just dawning upon the brightest mines, could not be suppressed; the conquerors became the pupils of their slaves, and both the Greeks and the Romans carried their newly-acquired knowledge home with them, enlarged upon it, and used it with skill and energy, so that the then known world was rapidly changed. Wherever the conquering arms of the Romans were carried, through Gaul into Germany, and over to Britain, through Greece into Asia Minor, and India, to the very gates of Cathay, the engineer followed and often led the way. Without his assistance and skill it would have been impossible for the Romans, in spite of their disciplined courage and their great administrative ability, to keep together for so long a period the vast incongruous empire they founded. The magnificent highways constructed by their engineers, the artificially improved and well-defended harbors selected by them, the temporary but very effective defences thrown around their camps, the strong walls and deep moats they built around their outlying fortifications in distant provinces, and the enormous engines of war for defence and offence, invented and brought into practical use by their mechanics, enabled the consuls and emperors of Rome to move and concentrate their legions with great rapidity, and to hold far away settlements of importance for many months against the fierce attacks of barbarians, until assistance could be brought forward from the center of life and energy at Rome. Besides the constant activity of the military engineer, for Rome was rarely without a great war on its hands, the civil engineer was never idle during the many centuries of Rome's glory. The whole empire, as it existed during the reign of the Antonii, bore witness of the scientific knowledge, and genius, and energy of its engineers. Not only in Italy, but also in every conquered province from the Atlantic Ocean to the borders of India, from the Baltic Sea to the Sahara Desert, the engineer of that period has left great monuments to attest his skill and fertility of mind. The many miles of costly aqueducts scattered all over the empire, the innumerable public and private baths located in every city founded by the Romans, the immense amphitheaters, the magnificent temples and palaces, the handsome and numerous stone bridges, some of them unrivaled in their magnitude even in modern times, the great network of canals for the uses of irrigation and navigation, often cut through mountains without the use or knowledge of any explosives—all of these stupendous works constitute the imperishable evidence of the important part the engineer has always played in advancing material prosperity and civilization.

Of all the great engineers that must have existed during these ancient times, Archimedes, of Syracuse, was probably the greatest mechanic; he is at least one of the few men of that type of whom we know anything definite. Everyone is familiar with the wonderful defense of his native city, as conducted by himself by means of his mechanical engines of war, until he was slain at the age of 78 by a common soldier, during a successful assault of the Romans. He is, above all others, the one man who laid the foundation of scientific research, the prosecution and improvements of which are the boast of the present day; but especially celebrated is his treatise on the principles of hydrostatics, which he studied during his travels in Egypt, and

upon which are erected all the theories of hydro-dynamics and hydraulic architecture, as practiced by the engineers of Italy and France after the Renaissance.

During that long period of the Dark Ages, from the downfall of the Roman Empire to the beginning of the 17th century, the civil engineer can hardly be said to have existed; brutal ignorance and mental darkness took again possession of the earth, nations were again annihilating and exhausting each other by constant wars, and every tyrant and religious fanatic seemed to be bent upon destroying what his ancestors had created for the benefit of mankind. The sciences and arts were only partly preserved, and only practiced in secret, either by a few monks superior to their kindred, or by the Free Masons, the Brothers of the Bridge, and a few other secret societies.

To Rome belongs the glory of having accomplished, by her enterprise and knowledge, more than any other nation of antiquity for the development of the resources of our globe, and to Italy belongs the credit of reviving culture, the sciences and the arts, after the religious bigotry that kept men's minds in bonds had been challenged and attacked by the liberty-loving people of northern Europe. It may be said that the civil engineer reappeared about the middle of the 17th century, when it became necessary to drain the marshes and submerged lands of Italy. Many eminent writers on philosophy and mathematics arose about that time, and the sound theories they established gave a new and better light for practical work to the engineer and mechanic. Galileo and Descartes were the great teachers of that period, and made rapid advances in the true understanding of the forces of nature. Since the time of Archimedes, the theory of equilibrium had been understood and practiced, but Galileo taught and explained, and believed in his theories of motion, and Descartes made complicated problems and tedious calculations soluble and comparatively easy by the introduction of algebra. Ever afterwards and up to the present time, progress, especially in mechanical engineering, has been constant, and within the last hundred years enormous.

When in the beginning of the last century England furnished a Newton, and Germany a Leibnitz, to teach the true principles of dynamics and of pure mechanics, the minds of practical engineers were prepared and ready to utilize their knowledge, and apply it successfully to the steam engine, invented by James Watt.

It can hardly be said that the civil engineer was known in England and France until the beginning of the last century. The celebrated school of *Ponts et Chausees* was established in France about the year 1720, and from it have since graduated some of the greatest mathematicians of Europe, and many able and practical engineers. England, although she had produced a few engineers of eminence in the construction of canals, and harbors and lighthouses, never gave evidence of all the technical skill that lay dormant among her people of sailors, merchants and country squires, until the steam engine was introduced in some of her factories. But then her progress was rapid, and her increase of manufactories, mining industries and commerce, grew to such enormous dimensions within a hundred years that she not only outstripped in influence and power all the other nations of Europe, but made the magnitude of Rome in her proudest days seem insignificant when compared to the wealth, and learning and strength of the British Empire.

The power of steam, and its application to the manufacture of iron, and to the production of every article of luxury and necessity that enters into our daily wants, has produced a far reaching revolution, not only in trade and commerce, and in the intercourse among the nations, but it has radically changed the very thoughts of men, until there is a larger gulf between our modern life and that of ancient Greece and Rome than there was between those cultured nations and the wild and naked hordes of the Scythian desert.

When finally the immortal Fulton applied steam for the propulsion of vessels through the water; when Stevenson ran his first locomotive engine from Liverpool to Manchester; and when Morse applied electricity to the telegraph, the revolution in our mode of life appeared almost completed, and man's power over the forces of nature and its elements, so constantly working against him, seemed

well nigh absolute. The human mind would be overawed by the results of its own achievements were it not so constituted by the rapid increase of physical science and the accumulating inventions and discoveries of mechanical contrivances and natural laws, as to look upon every new improvement as a matter of course, until the telephone, and the electric light and the electric engine have have become no greater wonder to our children "than the cooking of a dumpling. although the question as to how the apples got into it has been a mystery to some minds."

It would require volumes to recite with anything like justice the enormous works executed by public and private enterprise within the memory of living men; it would take column after column to record the names of eminent mathematicians and engineers who enlarged the scope of scientific knowledge and carried it into practical execution, and it is impossible in an address so limited as this is meant to be to dwell upon these interesting matters.

Leaving, therefore, out of consideration the great wealth expended within less than a century by the nations bordering on the Northern Atlantic in sanitary, and mining and military engineering; on the improvement of harbors and the construction of steamships and docks; on the development of cheaper methods in the manufacture of iron and steel; on the erection of immense establishments for supplying water, and light, and clothing, and hundreds of other daily necessities that have put it within the reach of the poorest laborer to live in more bodily comfort than the well-to-do citizen of antiquity—putting aside these important enterprises and looking only upon one great achievement of modern engineering, the construction of railroads all over the known world, then it becomes at once apparent what immense progress we have made in technical knowledge, and what infinite benefits mankind has derived from it.

When the future historian, perhaps Macaulay's New Zealander, shall chronicle the history of our times, this generation will not become celebrated by the beauty and grandeur of its architectural remains, nor by the romance and sublimity of its epic poems; but on account of its knowledge of natural law, of its technical ability, of its practical skill in engineering, and on account of the comfort, the health, the freedom and the enjoyment that these acquirements have brought within the reach of the humblest of mankind.

The treasures spent by the ancients during long centuries of their supremacy upon temples and other monuments of architecture fade into utter insignificance when compared with the fabulous sums of money expended on the construction of railroads alone within the last fifty years.

Poor's Manual of Railroads for 1884, gives in his review of the year 1883, for the United States alone, a mileage of 110,414 miles of railroad completed and in operation. They were constructed at a total cost in round figures of $7,500,000,000, and the gross earnings of that one year amounted to $833,000,000 of money, a sum larger than the revenues of the British Empire and the United States put together. All this vast amount of wealth has been invested, not to satisfy the vanity of some great general or emperor, not to glorify some pagan deity, or to cater to the taste of a turbulent populace, but in order to consolidate a great and free nation, to make possible the daily intercourse of a people living thousands of miles apart, and to exchange freely and rapidly and without interruption the products of their labor.

Surely the engineer is entitled to the lion's share of the credit due in bringing about this unparalleled prosperity of the country. From his brains originated all the designs for the large and substantial bridges that carry our highways and railroads over the largest rivers, and thereby overcome the barriers nature had put there. The engineer conceived and located, and he supervised and directed the host of laborers, craftsmen and mechanics that constructed and equipped the many thousand miles of railroads that made the rapid development of this country possible. Daily millions of people trust their lives and fortunes to the care and skill of the engineer, to his ability and to his integrity—on the decks of steamboats, crossing oceans and lakes, and ascending and descending rivers; on railroad trains, crossing continents with uninterrupted

rapidity; in our palace hotels and in public halls, yes, in the very privacy of our houses, the whole community, from the lowest to the highest, is constantly at the mercy of the engineer, and any neglect on his part would at once be the cause of a great calamity, or of far-reaching annoyance and inconvenience. Yet with all this responsibility resting upon his shoulders, and often overburdened with care and worry brought about by the dangers of wind, and fire, and water, the elements that constantly threaten to destroy in a few moments what he had so carefully constructed during weeks and months of anxious labor, and after years of honest toil the engineer finds his reward generally in obscurity, and without financial success, with his health destroyed and nothing to console him save the proud consciousness of having done his work well and to his own satisfaction.

The name of many an able engineer is entirely unknown, until by some misfortune and accident, or perhaps by some oversight of his own, one of his structures fails and causes the loss of life and property; then he becomes at once a public character and gets to be notorious, but not famous, as he had fondly hoped to be. Every school-boy has on his finger-ends the names of kings and Cæsars, and orators of Rome, but who knows the name of the engineer that built the "Appian Way" or the "Aqua Claudia?" Everybody who can read a newspaper is familiar with the names of the emperors, generals and statesmen, and public agitators of England, and Germany and France, yet there are but few men, even in the profession, that can call by name, or know anything of the lives of the men who built the London and Liverpool docks, the first Thames tunnel, or the steamship Great Eastern; of the history of the engineers who built the Mt. Cenis or the St. Gothard tunnels? I am afraid able and scientific engineers in this country are not much better known, and are much more rapidly forgotten than many a disreputable politician. The construction of our Pacific railroads have ceased to be wonders; the East River Bridge, the most stupendous piece of work ever conceived and completed, is used by the public with the same indifference as a ferry boat, and the great explosion of the rocks at Hell Gate, a feat of engineering skill so colossal and frightful in its responsibility, was forgotten a few days after it was fired.

One would naturally suppose that the construction and management of railroads would bring the engineer prominently to the front, but such is not the case. "Financiers" and "business men," without any knowledge whatever for the position, except their judgment, good or bad, are put above him, and his technical training is often a drawback to his advancement.

It is true there are a few conspicuous examples of railroads in this country that are entirely controlled by engineers, and I need hardly dwell upon the good result obtained, and upon how much such management is to their credit. It is a well-known fact, not only to railroad men, but to all the traveling public, that the railroads so controlled are infinitely superior, especially in their physical condition and equipment, to those managed by men without technical training, be they ever so able and energetic otherwise. I would like to go into detail upon this subject, but the natural modesty so common in our profession bids me halt.

It is, however, a constant wonder why the great men of finance and those who by their investment control the management of railroads, and who have suffered so much during periodic railroad depression, will learn nothing from experience, and will not accept the evidence of successful management by men technically trained for that purpose.

I think that nearly every engineer, at least all those who have devoted their time, and energy and health to the business, will agree with me about the subordinate position held by them, when compared with the other professions generally called classical and learned.

If this is admitted, it becomes the duty of everybody to look for the cause and to go to work and find a remedy. Perhaps a great many engineers neglect business habits and confine themselves too much to technical questions; others, again, pay no attention to culture and general literature; and others still become unpracticable because they devote all their time to pure science

and mechanics, which should be left to the Professor. But I believe the majority are kept so constantly down to the ordinary drudgery in order to get their bread, frequently without butter, that they lose all interest in study and fall behind their more fortunate neighbors. I have no doubt some blame for all this is due to our Polytechnic schools; their training is too narrow and not far-reaching enough to enable its graduates to cope successfully with the ever increasing demand made upon the profession both in Culture and Technic.

There is one grand remedy for this evil that I would not only suggest but urge upon all, namely: unity of action, harmony among ourselves, and mutual support. The lawyers give us a shining example in that direction. I have come in contact during my career with many eminent men in that profession, and I have always noticed that although during disputes in open court or before a master they frequently are full of wrath against each other, and spare neither satire nor innuendo to get the best of their opponent, yet outside of the arena, in private or in public, I have yet to hear the first unkind word, derogatory to his ability, spoken by one attorney against another.

INLAND NAVIGATIONS IN EUROPE.

By Sir CHARLES A. HARTLEY, K.C.M.G., M. Inst. C. E.

A Lecture before the Institution of Civil Engineers.

I.

The subject on which the Council has done me the honor to ask me to lecture this evening is so vast in its scope that I fear that in whatever way it may be treated, in the short space of time at the disposal of a lecturer, the result cannot fail to disappoint a portion, at least, of his audience.

With a view to minimize this natural feeling of disappointed expectation, I think it best to announce at once that my remarks to-night, instead of referring, as might naturally be expected, almost solely to inland navigation in connection with the United Kingdom, will direct your attention almost exclusively to certain important inland navigations and river improvements on the continent of Europe, with which, owing to my avocations abroad for a period of nearly thirty years, I am in a measure practically acquainted. In other words, I naturally prefer to confine my observations almost wholly, and with but one exception, to that part of the subject of my lecture on which I have some direct knowledge, namely, to systems of large river navigations in Europe—for time will not allow me to allude, even in the briefest way, to navigations in other quarters of the globe—rather than to dwell at length on the more popular subject of home navigations, concerning which the majority of my audience are doubtless already much better informed than myself, or, in any case, may speedily become so after reference to the many excellent publications on rivers and canals to be found in every public library, and especially on the well-stocked shelves of this Institution.

With regard to the actual cost of transport by inland waterways as compared to the cost by land, the question is evidently too large to be discussed with advantage on the present occasion. In what follows, therefore, I shall only touch incidentally on this important subject, and refer you for the latest and most authentic details thereon to the Report on Canals published in July, 1883, by order of the House of Commons.

The history of canals from the time of Alexander, the Ptolemies, and Marius, down to the days of Riquet, Brindley, Smeaton, Telford, Rennie, and De Lesseps, is published in countless volumes accessible to everyone. I need not, therefore, follow in the old track, and try to follow vary the recitals by conjectures concerning the priority of invention, by the Italians or Dutch in the fifteenth cen-

tury, of the lock, by which alone inland navigation eventually became generally applicable and useful; nor need I dwell on the fact that at home and abroad, during the latter half of the eighteenth century, there was as great a rage for canals as in the second quarter of this century for railroads.

I should not omit, however, to notice the circumstance that, great as has been the check by the introduction of railways to the construction of canals for the use of barges, the latter part of the present century will ever be famous for its great isthmian ship canal, such as the so-called artificial Bosphorus at Suez, which has already diverted the old lines of commerce in a remarkable manner, and the Panama Canal, which is apparently destined to effect a still more notable revolution in the old trade routes before the end, let us hope, of the present decade.

But as the theme allotted to me is inland navigation, I must perforce be silent on the topic of inter oceanic water-ways; and the same restriction applies to tidal ports and tidal rivers—a subject which is in the programme of a lecture to be delivered next month from this platform by a very distinguished member of this Institution, Mr. Thomas Stevenson, of Edinburgh.

As to the theoretical part of my subject, I have no new theories to propound, or old ones dressed up in a new garb, to place before you; but in saying this, I desire to indicate to any student in hydraulics who may be present to-night the best sources of information with which I am acquainted concerning the most generally accepted theories in this country, and the most recent experiments of value on the flow of water, namely, Dr. Robison's remarkable article under the head of "Rivers" in the last completed edition of the "Encyclopædia Britannica," and to the experiments of Major Cunningham, R.E., on the Ganges Canal.

INLAND NAVIGATION IN GREAT BRITAIN AND IRELAND.

The lower parts of the chief rivers of the United Kingdom are mostly arms of the sea, navigable at high water by ships of the largest burden. Higher up stream, where the tidal influence is gradually dimininished, they are generally navigable for ordinary river steamers, and, finally when the tide is no longer of any avail, they are in many cases canalized for the use of barges up to points which appear to be best adapted for the departure of entirely new water-ways to navigable channels in other river basins.

As a case in point, the Thames (218 miles in length) is navigable for the largest vessels from the Nore to London Bridge (48 miles), and thence for ordinary steamers to Teddington (20 miles), where the canalized portion of the river begins, and whence it is navigable as far as Lechlade, situated at 24 miles below Thames head. The total fall between the latter and London Bridge (170 miles) is 250 feet. Again, the Thames, at certain parts of its course above London Bridge, is united by means of a grand network of canals with the Solent, the Severn, the Mersey, the Humber, and the Trent; and thus, independently of its estuary, the Thames is in direct inland communication, not only with the English and Irish Channels and the North Sea, but with every inland town of importance south of the Tees. With reference to the estuary of the Thames, trustworthy evidence was taken before arbitrators in 1879–80, in a case concerning the navigable condition of the Thames, by which it appeared (1) that of the entire area of its basin, 5,162 square miles, 3,676 belonged to the non-tidal area, and 1,486 to the tidal portion below Teddington; (2) that the mean volume discharged from the tideless portion was 1,540 cubic feet per second over a period of twenty-five years ending 1878, or about 2,000 cubic feet per second at Crossness, 13 miles below London Bridge, from a total area of 4,661 square miles; and (3) that at Crossness the proportion of inland water (when the river is running moderately full) to tidal water (at an ordinary spring tide) is 1 in 26.

These figures are given with a view to enable comparisons to be made between our famous English river, on which is situated the chief commercial port and city in the world, and certain rivers on the Continent, shortly to come under review, of incomparably greater magnitude, but nevertheless of infinitely less importance as great highways of trade.

The absolute length of inland navigations in the British Isles seems to be rather a difficult matter to arrive at with

exactitude, for whilst Mr. Calcraft of the Board of Trade states it to be 2,688 miles in England and Wales, 256 in Ireland, and 85 in Scotland, or 3,020 miles in all, exclusive of the rivers Thames, Severn, Wye, Humber, Wear, and Tyne in England, the Shannon and other navigations in Ireland, and the Clyde, Forth, and Tay in Scotland, Mr. Conder, M. Inst. C.E., who has for many years past given special attention to railway construction and the cost of transport generally, estimates the length of inland waterways at 4,332 miles in England and Wales (of which 2,919 are canals and canalized rivers, and 1,413 navigable rivers), 755 in Ireland, and 354 in Scotland, or a total 5,442 miles. As to the cost of construction, the same authority has obligingly informed me that according to his researches the total cost of the canals and canalized rivers in England and Wales (4,332 miles) was £19,145,866, giving an average of £6,052 per mile, the minimum (Fen water canals, 431 miles) costing £4,000 per mile. and the maximum (Thames and Humber river and canal systems, 393 miles) £10,000 per mile, including the Regent's canal, which cost £120,000 per mile.* The carrying power of barges on British canals varies, with but few exceptions, from 20 to 80 tons when loaded down to draughts of from 3½ to 5 feet. The average dimensions of the locks, by which of course the size of the barges is regulated, are 80 feet by 14 feet, not taking into account of course the exceptional cases of the Weaver navigation (the best study in England at present of modern canal appliances), the new Aire and Calder canal, and the Gloucester and Berkley canal. There is a lock on English canals at every 1⅓ mile on an average, and the loss of time they occasion to barges is estimated at about two minutes per mile. Taking this retardation into account, the mean speed of barges in England by horse traction may be stated at 2½ miles per hour.

According to Mr. Conder, the working expenses of steam lighters on the Forth and Clyde Canal (35 miles long, and accommodating vessels of 8½ feet draught) are 0.23d. per ton per mile, including all expenses, but excluding interest on works; the average working expenses on all the English waterways are 0.26d. per ton per mile, or 0.37d. including 4¼ per per cent. interest on capital, and the cost on the Thames 0.10d., as compared with 0.083d. per ton per mile on the Aire and Calder Canal, for steam-tug expenses only.

There are no examples in the United Kingdom of cable-towing. A costly experiment of the system was tried on the Bridgewater navigation some years ago, but it was not adopted there, as the distances between the locks are short and the navigation tortuous.

No account, however short, of British waterways should omit to mention Telford's masterpiece, the Caledonian Canal. This celebrated work has a length of 60½ miles, of which 37½ are natural lake navigation, and 23 are artificial or canal navigation. The standard depth of the canal is 18 feet, giving access to vessels 160 feet in length, 38 feet beam, and 17 feet draught. The summit level is 102 feet above the sea, and at Corpach, its southern extremity, eight locks are clustered together up the side of a hill, to overcome a height of 64 feet. The cost of the canal was about £1,000,000 sterling.

INLAND NAVIGATIONS OF THE CONTINENT OF EUROPE.

It is a far cry from England to Russia, but as this lecture is meant to embrace inland navigations generally throughout Europe, a succession of long and sudden leaps is unavoidable in a voyage covering so much ground. Hence my excuse for hurrying on without further preamble to the most northerly country of the Continent, with the intention of then working west about to Roumania, which marches with her gigantic neighbor along mid-channel of the lower Pruth to its mouth near Reni, and thence by the left bank of the Danube and the new frontier line of the Kilia mouths to the Black Sea.

RUSSIA IN EUROPE.

European Russia is forty times larger than England, having in round numbers a length of 1,600 miles from the confines of Scandinavia, Germany and Austria, a width of 1,300 miles from the Arctic Ocean to the Black Sea, and a total area

* The total length of railways open for traffic in the United Kingdom on the 1st January, 1884, was 18,681 miles, and the total capital paid up thereon £784,921,000, giving an average of £42,000 per mile.

of 2,000,000 square miles, or more than one-half that of Europe.

With the exception of the little group of the Valdai Hills the main divisions of European Russia are the frozen "tundras" of the Arctic coast, the rock and Lake Plateau of Finland, the great forest and corn-bearing land of the central region, and the vast treeless "steppes" or pastoral land of the south and south-west, the chief characteristic of the whole landscape being that of an apparently illimitable gently-rolling plane, without a hill in view to break the monotony of the horizon. Thanks, however, to its comparatively low elevation this enormous region enjoys a river and lake system of navigation on an immense scale, and in order to complete Nature's handiwork—for hitherto Russian rivers have been little improved by the hand of man—a well-considered system of artificial canals has been established, by means of which the whole country can readily be traversed by water from end to end. European Russia possesses 19,000 miles of navigable waterway, and 38,000 miles of raft-bearing rivers. In summer these great highways transport raw products to the south and west, and receive back manufactured goods, whilst in the long winter months, from October to May in the north, and from November to April in the south, all inland traffic is necessarily carried on either by means of railways, of which there is already a length of 16,000 miles in European Russia, or by sledges over the frozen ground in districts where railways are still unmade or temporarily buried in snow.

The chief inland water-ways of European Russia will now be briefly passed in review, after drawing attention to the fact that the great watershed of Europe, that which separates its northern from its southern drainage—coincides throughout the eastern half of the continent with a low range of hills, which, in their greatest elevation, the Valdai plateau, hardly reach more than 1,100 feet, and which widens out in some parts into an expanse of marsh.

Thus, to the north of this watershed the Petchora flows into the Arctic Ocean, and the Dwina into the White Sea, to the north-west the Neva and the Duna fall into the Baltic, to the south-east the Ural and Volga fall into the Caspian Sea, and to the south, the Don, the Dnieper, the Bug and Dniester fall into the Black Sea.

The Petchora, 915 miles in length,* with a drainage area of 127,000 miles, has but 10 feet of water on its bar, and is only free from ice during a third of the year. Nevertheless its traffic in cereals and raw produce in the short summer season is very considerable.

The Dwina has a course of 650 miles, and becomes navigable on receiving the Vichegda, where it turns to the north; but though at the port of Archangel the water is very deep it is only accessible to vessels of less draught than 14 feet—maximum depth over the deepest of the four mouths of the river which empty themselves into the gulf of the Dwina, about 30 miles below Archangel.

The Ural has a course of 1,446 miles, and drains an area of 95,000 square miles, but the volume of its waters does not correspond with its length and the extent of its basin as compared with rivers in moister climates. It is navigable for small craft for most of its length, and enters the Caspian by three mouths of great width but insignificant depth.

The Volga, the longest river in Europe, and the chief commercial road of the whole Russian Empire, rises in the Valdai Hills, at an elevation of 663 feet above the Caspian Sea, into which it flows through upwards of seventy mouths, after a tortuous course of more than 2,000 miles. Its drainage area is 563,000 square miles. With its tributaries, it affords 7,200 miles of navigation, and is connected by canals with the White and Black Seas, the Baltic and the Azov. The Volga first becomes navigable for small steamers at Tver, whence it flows almost due east to its confluence with the River Oka (which drains 93,000 square miles) at Nijni Novgorod, so celebrated for its great fairs, and then on in the same direction to the large manufacturing and semi-Asiatic town of Kazan. Hence to the Caspian Sea, there are said to be only four towns on the left bank of the river, as against more than thirty on the right; and this is readily accounted for by the fact that it is chiefly the left bank that is

* The areas of the drainage basins of Russia and Germany are mostly after Strelbitsky. All measurements are in English statute miles of 5,280 feet.

liable to be flooded, the right bank being mostly the higher and steeper of the two —a remark, it may be said in passing, that also applies to the Dnieper, the Don, and the lower Danube. About 50 miles below Kazan and 300 below Nijni Novgorod, the Volga receives the waters of its chief feeder, the river Kama, which rises in the Ural mountains, and drains 200,000 square miles. As upwards of 900 miles of its total length of 980 are navigable, and as it is the great artery of communication with Siberia, the traffic of the Kama is very important. From its confluence with the Volga to Astrakhan, the great river flows nearly south for 1,200 miles, and, owing to the dryness of the climate, receives no other tributary of importance in the remainder of its course to the sea. In this distance it spreads out in many places to a width of several thousand feet, with depths varying from 3 feet at dry seasons, where the width is abnormal, to 50 feet and upwards in the concavities of sharp bends and in narrow places.

Hitherto no permanent works have been undertaken to improve the navigation of the Volga, and the Russian Government will hesitate a long time yet, I think, before rushing into heavy works for that purpose, for not only would they be exceedingly costly, but their effect would be very uncertain. Meanwhile, in the lower part of the river, the removal of shoals which are formed annually by the spring floods is effected by dredging, by provisional lattice groynes, and, during the last three or four years, by what is called a new system of iron harrows, which are said to have doubled the navigable depth over certain shoals in a few days, and, in one instance, at the Chebocksarsk shoal, where the depth was only 2 feet 4 inches right across the river, to have deepened the water 3 feet in six days, over a sufficiently wide channel, and to have given a depth therein of two meters in a fortnight. This reference to shallow water in the Volga will give an idea of the difficulties the navigation has to contend with at certain seasons of the year; nevertheless, upwards of six hundred steamers navigate the river and its chief tributaries, and trade goes on increasing rapidly.

Six days are generally needed to steam down from Nijni Novgorod to Astrakhan. Stoppages, both up and down stream, are always made at Tsaritzyn, on the right bank, which is connected by rail with Kalatch, on the left bank of the Don. The distance between the Volga and the Don at Tsaritzyn is only 49 miles, but as yet the only water communication between these two great streams is by means of the Upa canal, which connects the Oka with one of the upper reaches of the Don, thus uniting the Caspian Sea with the Azov.

The flourishing town of Astrakhan is situated on the right bank of the Volga, at a few miles above the head of the delta, 1,440 miles below Nijni Novgorod, 320 below Tsaritzyn, and 50 from the Caspian Sea. Although the Volga is longer than the Danube, and the area of its catchment basin 90 per cent greater, the volume discharged by the Volga is less than two-thirds of that discharged by the Danube, a circumstance which is explained by the fact that in the region traversed by the former there is relatively a much smaller rainfall than in the westernmost parts of Europe.

At the numerous mouths of the Volga, which frequently change in direction and volume, the south, or principal one, is happily kept open for the passage of small steamers by the action of the prevailing S S.W. winds, which tend to drive the detritus northward, and thus partly to choke up the subsidiary channels to the north-east.

This inland sea has an area of 160,000 square miles, and the level of its surface is 84 feet below that of the Black Sea. Its trade is now very important, owing principally to the great increase of late years in the production of petroleum from wells sunk near that ancient seat of fire-worship, the Port of Baku. In 1883 the transport by rail and steamer of this industry alone amounted to 206,000 tons, of which more than one-half was produced by the enterprising Swedish firm of Nobel Brothers. A large fleet of cistern steamers are already employed in connection with this trade, and it will be interesting to engineers to watch the effect on the water traffic when the means now in progress to facilitate the land transport by rail and lines of iron tubing have been perfected. By this combined system of carriage it is anticipated that ultimately there will be no

difficulty in exporting the 250,000,000 gallons a year which experts assert can regularly be obtained from the Caucasian regions, a supply, it may be added, which is equal to the present wants of the whole world. Apropos of this interesting question of the petroleum trade it may not be out of place to quote a passage from a letter I received last month from H.B.M.'s Vice Consul at Odessa. He says: "We have in port a small, light-draught screw steamer—150 tons burden, dead weight—called the Samuel Owen, which has just arrived from Baku (Caspian Sea) *via* the Volga, the Marie system of canals, Lake Oneiga, River Neva, and thence around Europe to Odessa." Now, as the distance by land in a straight line from Baku to Odessa is less than 1,000 miles, and as the distance steamed over by the Samuel Owen must have been fully 8,000 miles, it appears to me that the voyage of this vessel is a remarkable illustration of the preference that is given, in certain cases, to water over land transport, even when the former mode of transport involves the delay attending an extraordinarily circuitous navigation by lakes, rivers, canals and narrow seas, to attain the end in view.

The Don rises in the Ivan lake, 586 ft. above the sea; its length is 980 miles, and its drainage area 170,000 square miles. This river is navigable for large rafts of timber down to the mouth of its first great tributary, the Toronjo, at Tavrovsky, on the left bank (where Peter the Great built his ships of war for the Black Sea), and thence to Kalatch it is navigated by small steamers. From Kalatch, which, as we have seen, approaches within 49 miles of the Volga, large freight steamers start several times a week for Rostov, the largest commercial town in Russia after Odessa, and situated on the right bank of the river at the head of the delta. The quantity of merchandise floated down, including the traffic of the Donetz, which enters the Don between Kalatch and Rostov, as well as that of the Sosna, another tributary which enters it between Voronej and Kalatch, is above 200,000 tons annually, exclusive of large deliveries of antracite coal, which is obtained from Novo Tcherkash and Lugan (about 100 miles below Rostov), and sent down the Don for the use of the Russian steamers in the Azov.

A short distance below Rostov, where, according to my own observations, the sectional area of the river at low water is 23,300 square feet, the Don splits up into two channels, which ultimately give birth to five separate mouths, at the deepest of which, the Perevoloka mouth, 25 miles below Rostov, and 15 miles from the Taganrog roadstead, the available depth is rarely more than 6 feet. During the summer of 1882, and in November, 1884, however, all the bars of the Don were completely dry for several hours, owing to the effect produced by a long-continued east wind. On the other hand, in 1866 (when the mouth of the river were surveyed under my direction), a long series of hydrographic observations recorded the interesting fact that after a long and stiff blow from the W.S.W., and therefore from seaward, the water at the Perevoloka mouth rose 9 feet above its ordinary level, thus giving a momentary depth of 15 feet on the bar, and so causing the current to flow upstream past Rostov with considerable velocity.

After this description of the mouths of the Don, it need not be said that the river is only accessible to coasters of light draught. Sea-going vessels either take in their cargoes from lighters in the straits of Kertch, where there is now a depth of 15 feet, or in the roadstead of Taganrog, which, on account of shallow water, is 10 miles distant from the port of Taganrog. Taganrog is one of the three privileged ports of the empire for the importation of foreign goods, and the great entrepôt for the commerce of the Volga and the Don.

The Dneiper drains an area of 204,000 square miles, and rises not far from the source of the Volga. In its length of 1,060 miles it flows nearly south from Smolensk to Kiev, below which its direction south-east to Ekaterinoslav, and thence south and south-west to the Black Sea. Its first great tributary below Smolensk is the River Berezina (which is joined to a branch of the river Duna by the Berezina Canal); but its most important feeder is the Pripet, which joins the Dneiper at about 60 miles above the city of Kiev, the "Jerusalem" of Russia. The Pripet is 380 miles in length, and rises within a few miles of the right bank of the northern Bug, which flows into the

Vistula. By the Oginsky Canal the Pripet is connected with a branch of the river Niemen, and thus there is an alternative means of inland water communication between the Black Sea and the Baltic. The Desna, the third tributary of importance, joins the Dneiper on its left bank at Kiev, and contributes a large quota of trade to the main river in the early summer, when it is navigable as far as Briansk in the province of Orel. At Kiev, where, as we all know, the Dneiper is spanned by Vignoles' magnificent suspension bridge, the river is 1,500 feet wide, but thence to Krementchug, about 100 miles above Ekaterinoslav, it occasionally exceeds 1 mile in width. The minimum depth between Kiev and Ekaterinoslav is 3 feet. At Krementchug a large trade is carried on in tallow, salt, grain, and beet-root sugar, and large storehouses are provided for the half-manufactured produce brought down the Dneiper and its tributaries from the provinces through which they flow, as well as for goods brought overland from the interior.

Steamers ply daily in summer between Kiev and Krementchug, and every other day between the latter and Ekaterinoslav, an important town on the right bank, about 60 miles above Alexandrovsk, a large port on the left bank, at the foot of the cataracts of the Dneiper. This great obstruction to the navigation, which I inspected in 1873 at the request of the Russian Black Sea Steam Navigation Company, is caused by a granite outshoot of the Carpathians, and consists of nine distinct rapids in a length of 47 miles, the total fall being 107 feet. The most formidable of these obstacles are the Kiodatsky, Nenasitetsky, the insatiable, and Volingsky Rapids, their average length being only 7,700 feet, with a total fall of 34 feet. Several abortive attempts were made between 1788 and 1883 to improve the navigation by means of side-cuttings near the shoreline, but no improvement of any kind was effected till 1853, when, after ten years' work, a series of canals were formed in the bed of the river, and protected at the sides by parallel walls of rock-work, furnished with splayed guiding-walls facing up-stream, with the view of allowing vessels of small draught to make use of them at certain seasons of the year, when the rapids would otherwise be impassable. In practice, however, their only use has been to allow of the occasional passage of undecked flat-bottomed barges carrying from 5 to 7 tons, and drawing 18 inches at extreme low water. At all other seasons the confined artificial channels, which have a width of about 140 feet, are regarded as mere traps at each one of the rapids, and are therefore always carefully avoided by descending vessels. No cargo-boats ever ascend the rapids, and the whole trade over them is consequently limited to rafts of timber and to raw and also manufactured produce floated downstream from long distances in lightly-constructed barges, which are broken up and the wood used for building purposes on their arrival at Kherson, a languishing port on the right bank at the head of the Delta, 216 miles below Alexandrovsk.

Immediately after passing Kherson, the Dnieper divides into several channels, and finally delivers its waters into the Bay of Kherson by nine mouths, at the deepest of which, by the aid of occasional dredging, a depth of 10 feet is generally maintained.

In spring, when barges drawing from 5 to 6 feet can descend the river from the foot of the rapids to Kherson, there are barges carrying 100,000 tons plying between Alexandrovsk and Odessa, a distance of 306 miles, at an average freight of 7s. per ton. At the low-water season, however, the rates sometimes rise to 15s. per ton.

The Southern Bug rises in Podolia, and after a course of 430 miles enters the Bay of Kherson at 30 miles west of the town of Kherson. It drains 26,000 square miles, and can be navigated by craft drawing 6 feet for about 80 miles above the town of Nicolaev, which stands on the east bank of the river at 20 miles from its mouth, and at the junction of the rivers Ingul and Bug. Nicolaev is the Russian arsenal of the Black Sea, and ships-of-war are built and launched here, and pass into the Bug from the Ingul by a channel 20 feet deep, a depth which diminishes to 17 feet at the entrance of Kherson Bay, off Kinburn. The tonnage of vessels cleared from the port of Nicolaev with cargoes of grain in 1882 was 162,000, a shipment which is much below the general average.

The Dniester rises in the Carpathian Mountains in Galicia, and flows south-east into Russia. It forms the boundary between Bessarabia on the right, and Podolia and Kherson on the left, and its waters, after passing through a wide and shallow estuary below Akerman, enter the Black Sea on a low sandy shore between Odessa and the Danube mouths. Its total length is 640 miles, and, like the Bug, having no tributaries of importance, it only drains 30,000 square miles. Its channel is broken up by rapids near Bender, and below that historic town is only navigable for vessels drawing less than 8 feet, whilst at its principal mouths the depth varies from 4 to 6 feet.

A long leap backwards must now be made to the north of Russia, to carry out my programme to work west about from the North Sea to the Danube mouths.

The Baltic has been well termed an estuary rather than a sea, receiving as it does a number of rivers, none of them individually of great size, but collectively draining an area equal to one-fifth of the entire area of Europe. Near the mouths of these rivers, the depth of water becomes greatly diminished, and, like the Black and Caspian Seas, there being little or no tide, and the water being comparatively fresh, the surface of the Baltic, which is emphatically a shallow sea, soon becomes frozen. Hence all its ports are sealed up for more than a third of the year, and during this long period the inland navigation of north-eastern Europe is entirely suspended.

The Neva is only 34 miles long, and its waters are immediately derived from Lake Ladoga, which, having a surface of 7,000 square miles, is the largest fresh-water lake in Europe. The Ladoga receives the contributions of numerous other lakes, including Lake Onega, which covers area of 3,800 miles, or seventeen times that of the Lake of Geneva. The entire area drained by the Neva is 112,000 square miles, and through Lade Onega it is connected with the Dwina and the Volga by canals, through which small vessels can pass from the Baltic into either the White Sea or the Caspian.

Before taking leave of the Neva, a few words should be said regarding the new canal, which now unites the commercial harbor of St. Petersburgh and the military port of Cronstadt. When I journeyed between these two places on the ice in mid-channel in the upper part of the Gulf of Finland, in 1869, the carrying trade through the Baltic, to and from St. Petersburgh, had to be done almost entirely by transhipment at Cronstadt, as at that time lighters only could cross the 8 to 9 feet of water at the long bar of the Neva. The construction of a maritime canal to unite St. Petersburgh and Cronstadt, designed originally by Peter the Great in 1725, was only begun in 1878, and thrown open to commerce in October last. This canal is 18 miles in length, with a floor width of 276 feet, and an actual depth of 20 feet. This depth is now being increased to 22 feet at ordinary low water. With regard to this level, it is worthy of notice that, during the construction of the works, strong winds from seaward raised the level of the gulf 9 feet on one occasion, whilst on another a strong N. E. wind lowered the water 5 feet; the extreme difference being 14 feet, as compared with 15 feet from the same causes at the mouths of the Don.

The estimated cost of the St. Petersburgh Canal is 10,000,000 roubles, a sum well spent, in my opinion, on such a work, although, notwithstanding its obvious utility, both from a commercial and strategical point of view, there are many self-dubbed authorities, especially among those interested in the lightering trade, who maintain, as invariably happens in similar cases, that the canalization will turn out anything but a success in practice.

The Duna rises near the source of the Volga, and drains an area of 33,000 square miles. Its length is 470 miles, and its general direction north-west. It forms the frontier between Livonia and Courland, and enters the Gulf of Riga 7 miles below the town of Riga. The navigation of the river is obstructed by rocks and sandbanks, but during the floods of spring and autumn its products are readily transported in barges to the Baltic. The depth of the navigable channel at Riga is 17 feet, but at the entrance to the Duna, at the head of the north pier, 9 miles below Riga, the depth in 1881 was only 14 feet.

The total length of the canals in

European Russia is about 900 miles. In most instances they have been formed with but little difficulty across the gentle undulations of the great watershed, thus uniting, as we have seen, the head-waters of rivers which have their outlets at opposite extremities of the continent.

SWEDEN.

Sweden abounds in lakes, which cover more than 14,000 square miles of its surface. Of these the Wenern and the Wettern are the largest, the former having an area of 2,400 square miles, and the latter 760. The Mälar Lake, with its one thousand three hundred beautiful islands of all sizes; is also of great extent. None of the rivers are navigable, excepting those which have been made so artificially, and nearly all are ob structed by cataracts and rapids. Nevertheless Sweden has remarkable facilities for internal navigation, during the seven months that the country is free from ice, by means of a series of lakes, rivers, and bays, connected by more than 300 miles of canals. These furnish direct water communication between the Baltic and Gothenburg, the chief commercial town of Sweden, situated upon the estuary of the Gotha river, 5 miles from the Cattegat. Plans for effecting this communi cation were devised long before they were carried out. In 1800 the Trollhattan or Gotha canal, at the head of the river Gotha, where it descends 108 feet in 5 miles, was opened to the navigation, and improved and widened to the dimensions of the Gotha canal between 1836 and 1844. This celebrated canal, which I visited in 1880, was founded in the beginning of this century by Count Von Platen, the De Lesseps of his day. In 1808, he summoned to his aid Mr. Tel ford, the first President of this Institution, who, after visiting the ground, prepared and sent in a series of detailed plans and sections, with an elaborate report on the subject. His plans were accepted, and the works were begun in the following year, but although the West Gotha canal was opened for traffic in 1822, the two Swedish seas were not connected before 1832. Of the entire distance of 370 miles between Stockholm and Gothenburg, only about 50 are canal, and the same distance along the coast of the Baltic, the remaining 270 being through lakes, bays and rivers. The canal is now everywhere 48 feet wide at the bottom, 90 at the surface, and 10 feet deep. In 1855 it was thrown open to steamers. Its most elevated point is Lake Wiken, between Wettern and Wenern, where it is 300 feet above the level of the sea. The descent is made by vessels through thirty-seven locks, or seventy-four from sea to sea; and as several of the lock chambers, which are 120 feet long and 24 broad, are grouped together where the ground is steep, vessels have the appearance every here and there of slowly descending a flight of gigantic stairs.

The total length of the railways in Sweden and Norway is 3,637 miles, of which one-third belongs to the State.

GERMANY.

The German empire owns parts of seven river valleys, and three large coast streams. Of the latter, the Pregel flows to the Baltic, and the Eider and Ems to the North Sea; of the former, the Niemen (or Memel in German), Vistula and Oder, flow to the Baltic; the Elbe, Weser and Rhine, to the North, and the Danube to the Black Sea. Of these seven large rivers, the Weser is the only one which belongs entirely to the German empire; of the Elbe and Oder the larger part; of the Rhine the larger half; but of the Danube only one-fifth part. The hydrography of all these rivers, with the exception of the Danube, will now be briefly described.

The drainage area of the Niemen (35,000 square miles) is conterminous with that of the Duna, and of about the same extent. The Niemen rises in Russia, becomes navigable at Grodno, and divides at Winge into the Russ and the Gilge, both of which fall into the Kurisches-Haff, one of those peculiar lagoons characteristic of the shores of the Baltic opposite their river mouths. The Niemen enters the sea at the port of Memel, the central point of the timber trade of the Baltic. The depth of its harbor is 23 feet; but on the bar of the river, 2 miles below the town, the depth is 18 feet only. By means of an artificial canal between the Upper Niemen and the Pripet, already described, vessels can pass from Memel to the Black Sea.

The Vistula rises in Austrian Silesia, in the Carpathian Mountains, at 2,000 feet above the level of the sea, and its basin drains 74,000 square miles, including Russian and Prussian Poland. In its length of 600 miles, it flows past Kracow and Warsaw, becomes navigable for vessels of from 7 feet to 8 feet draught at ordinary high-water level at the German frontier and carries this depth to its principal mouth at Plonsdorf, about 5 miles east of Dantzig, the chief port of Germany in the Baltic.

Dantzig is situated on the west, or left bank of an old arm of the Vistula, through which the current ceased to flow on the 31st of January, 1840, when, owing to the effect of a sudden break up of the ice, the river formed for itself a new mouth at Frondorf, nine miles below the old mouth at Neufahrwasser, which is now completely closed. In the following year a lock, with 10 feet of water on its sill, was built across the old arm close to the new entrance, to ensure the easy passage of river craft between Dantzig and the interior of the country, and in 1846 the old lock at Neufahrwasser, constructed in 1001–1805, being no longer needed, was destroyed, and a wide open channel substituted in its place.

From Dantzig to Neufahrwasser, a distance of 5 miles, and thence to deep water at the head of the east pier, the dredging of a channel 200 feet wide and 23 feet deep is now on the eve of completion.

In 1848 the navigation of the Vistula between the new mouth and the head of the delta, where the river bifurcates into the Nogat, or east arm of the river, and the Dantzig, or west arm, became so difficult that works of correction were begun in that year by the Prussian Government to ensure a regular flow of water through both branches, and, as it was hoped, to improve their navigable condition as well. In 1858, a short time after the works were completed, I visited the ground and obtained through the kindness of the Government engineers, certain technical information of interest, which I venture to reproduce in this place, as it refers to a very delicate operation in river engineering, namely, that of radically changing with success the relative flow of two branches of a great river at a point where they separate from their parent stem never to reunite. In the Vistula, immediately above the head of the delta, the volume discharged at zero or extreme low water is estimated at 8,766 cubic feet per second, and at high water, when its level stands at 10½ feet above zero, at 76,700 cubic feet per second. Of this quantity, three hundred years ago, two-thirds passed by the Dantzig branch, and one-third by the Nogat. The latter, however, having a steeper slope than its sister branch, went on gradually increasing in volume, until, in 1840, the proportions were completely reversed, and it appeared highly probable that unless the art of the engineer stepped in before long to re-establish the old order of things and to fix the flow at the bifurcation, the Dantzig branch would silt up altogether. Hence the contemplated works had principally in view the restoration of the old *regime*, by means of which the Nogat, instead of withdrawing two-thirds of the total volume of the main river, should have its flow permanently brought back to the original proportion of one-third only.

The works were admirably executed, and principally consisted of the cutting of an entirely new channel, furnished with incorrodible sills and revetments for the waters of the Nogat; the blocking up of its old channel by several substantial dams; the construction of extensive training works from the fork down to Dirchau on the one branch, and Marienburg on the other; and the construction of twenty-six massive ice-breakers across the new Nogat entrance.

The result of the works (the cost of which is estimated at £600,000) has proved:—1st. That the discharge of the Nogat as compared with that of the undivided Vistula, is only 10 per cent. at low water, 24 per cent. at ordinary water-level, and 28 per cent. at high water, and consequently the discharge of the Dantzig branch 90 per cent., 76 per cent., and 72 per cent. respectively of the total flow at the same periods. 2d. That a good navigable channel everywhere 8 feet deep is now available in the Dantzig branch, whilst at low water in the sadly impoverished Nogat the channel is impassable for vessels drawing more than 3 feet. 3d. That the ice-breakers have produced the desired effect of diverting all the largest ice-floes to the sea by the Dantzig branch;

and 4th. That the general result has apparently been to improve one branch of the river at the expense of the other.

In connection with the mouths of the Vistula, it should be further observed that the Nogat discharges itself into the Frische Haff by several very shallow channels near Elbing, where a lateral artificial canal permits steamers of small draught to enter the Haff and then to steer direct either for the mouth of the river Pregel, or for the Port of Pillau on the Baltic. The entrance to this seaport has deepened itself 10 feet since the completion of its piers in 1846, and has now a depth of 24 feet; but from its harbor to the mouth of the Pregel, 19 miles, and thence for 4 miles further on, to the great corn-exporting port of Königsburg, the channels through the Haff and river only admit of the passage of vessels drawing less than 10 feet.

The Oder rises in Moravia at an elevation of 1,000 feet above the sea, enters Prussian Silesia, traverses the provinces of Brandenburg and Pomerania, and after a course of 550 miles, empties its waters through the Stettin Haff or estuary into the Baltic. Its basin has an area of 50,000 square miles. The result of the large expenditure which has been incurred with the view of improving the navigation of the Oder, has thus far proved satisfactory. Works have been going on for some years past, and are now nearly accomplished, with the view of securing a depth of 3½ feet between Ratibor, near the frontier of Silesia and Schwedt, 400 miles lower down. The other works of importance which have lately been determined on in connection with this river, are: the extension upwards of the navigable channel from Ratibor to Oderberg; the construction of another Oder-Spree canal, leaving the Oder opposite the mouth of the Werthe; whilst a project for a ship-canal connecting the Oder and the Danube has been planned in detail, and its execution seriously entertained.

The estuary of the Oder may be said to begin at Stettin, from which to place Swinemünde, a distance of 50 miles, a channel has lately been dredged to a depth of 20 feet over a width varying from 250 feet to 400 feet, so that sea-going vessels of 19 feet draught can now trade with facility from the mouth of the Oder to Stettin without transhipment of cargo.

The Elbe rises in the north-east of Bohemia, and one of its sources is about 4,500 feet above the level of the sea. It drains an area of 55,000 square miles, and next to the Rhine is the most important of German rivers. It enters the North Sea near Cuxhaven, and like the Duna, Niemen, Vistula and Oder, its general flow is in a north-westerly direction. Its principal affluents are the Moldau and Eger, both of which enter the Elbe on its left bank above the Bohemian town of Aussig, not far from the German frontier. Notwithstanding the comparatively favorable state of the river at ordinary water-level, the condition of its bed in some places at extreme low water was so deplorable in 1870 that a technical commission, which was convoked at that time, recommended the execution of a project which had for its object the permanent acquisition of a channel of a minimum depth of 2 feet 10 inches from the Bohemian frontier downwards.

According to Mr. Ludwig Hagen, who has the supervision of all the Prussian streams, the minimum depths at ordinary water are now 5 feet from the Bohemian-Saxon frontier to the Saxon-Prussian frontier at Anhalt (163 miles), 5 to 6 feet from Anhalt to Havelburg (103 miles), and 6 to 6½ feet from Havelburg to Hamburg (121 miles). The practice of towing vessels of from 30 to 450 tons burden by men and horses between Aussig and Hamburg, has been almost entirely abandoned. As early as 1866, chain-tugs were running on 200 miles of its course, and in 1874 this mode of traction had been so much increased that there were then twenty-eight tugs running regularly between Hamburg and Aussig. These tugs are 138 to 150 feet long, 24 feet wide, with 18 inches draught. On the Upper Elbe the average tow is from four to eight large barges, and taking the ice into consideration, there are about 300 towing days in a year. On this river it has been found, as elsewhere, that vessels of large tonnage pay best. Thus, to the Hamburg Magdeburg Navigation Company (which has perhaps had more experience in the *modus operandi* of steam-tugging in inland waters than any other corporation in the world) the cost of transporting a

cargo from Hamburg to Dresden, a distance of 350 miles, for barges of 150 tons, 300 tons, and 400 tons, is, respectively, 11s. 6d., 9s. 9½d., and 9s. 4d., per ton up stream, and 4s. 4½d., 3s. 2½d., and 2s. 9½d. per ton down stream. These figures are given on the authority of Mr. Bauer, and have been selected as a fair type of the present method of traction with its precise cost on one of the best conducted inland water routes on the continent.

The formation of an internal navigation to join the Elbe, the Oder and the Vistula, has been successfully accomplished partly by the aid of secondary rivers and partly by canals. The canal of Mulrose unites the Oder and the Spree; the latter being a navigable river falling into the Havel, which in its turn falls into the Elbe near Havelburg. But the navigation from the Oder to the Elbe being difficult by this route, another communication was made by the Finow canal and a chain of lakes stretching from the Oder at Oderburg to the Elbe near Magdeburg. The Elbe being in this way connected with the Oder by a comparatively easy navigation, the latter has been united to the Vistula, partly by the river Netze and partly by a canal joining that river to the Brahe, which falls into the Vistula near Bromberg. A vast inland navigation has thus been completed by which barges of 110 to 125 tons burden, and drawing 3 feet at ordinary low-water level, can pass freely through the whole extent of country from Hamburg to Dantzig.

Before quitting the Baltic, a few words should be said with reference to an existing water communication across Holstein, and of a maritime canal which is shortly to be cut between Kiel and the mouth of the Elbe. The Holstein canal, formerly belonging to Denmark, is of great importance, joining, as it does the Baltic with the river Eider, which falls into the North Sea. The Eider is navigable for vessels of 9 feet draught from Tonning, near its mouth, to Rendsburg, where it is joined by the canal which communicates with the Baltic at Holtenau, about three miles north of Kiel, the chief naval arsenal of Germany. The canal is 26 miles long, and the excavated portion is 52 ft. wide at the bottom, and 9½ feet deep. It was opened in 1885 at a cost of £500,000.

The projected ship canal is to run from the mouth of the Elbe near Glückstadt to a point near Kiel, and is to be of such dimensions as to pass the largest war vessels in the German navy from sea to sea. When completed, this important undertaking will be of the greatest benefit to large steamers trading to the Baltic ports, and will supersede the present circuitous voyage by Jutland and the Sound, if the dues imposed are not prohibitory to the passage of merchant vessels.

The Weser has a length of 355 miles, and drains 18,000 square miles. In its upper part it traverses a mountainous district, and only emerges on the plain at Münden, whence to Bremen the distance is 230 miles. The system of improvement of the lower part of the river commenced in 1823 with the intention of securing a depth throughout of 1½ foot at extreme low water. Up to this time, however, the depth already obtained ranges from 1½ foot to 3 feet, thanks to the construction of an extensive series of groynes and training walls, and of a separate canal to avoid a difficult obstruction above Hameln. The barges now in use below Munden vary from 80 to 260 tons burden, and the proportion of laden vessels bound down stream is as six to one bound up stream. Works are in progress to still further improve the navigation of the Weser and its tributaries, especially the Fulda, down to Bremen, the second commercial town of Germany, situated on the right bank of the river about 50 miles from the sea. The depth of water at Bremen is only 8 feet, but at its sea port Bremenhaven vessels drawing 22 feet can enter safely, and, as at Hamburg, Bremenhaven is free from ice nearly all the year round.

The Ems rises on the confines of Lippe Detmold. It flows in a northerly direction, through Westphalia and Hanover, and empties itself through the Dollart estuary into the North Sea, near the town of Emden. It has a length of 200 miles, and is navigable for vessels of 200 tons to a distance of 14 miles from its mouth, and for small vessels as far as the town of Rheine, 75 miles from the sea.

The Rhine rises in Switzerland at an elevation 7,240 feet above the sea, and its basin receives the drainage of 76,000 square miles. Its total length is 850 miles. It first becomes navigable for

rafts at Reichenau, but thence to Bâle, 820 feet above the sea, its navigation is difficult, and in many cases impossible, owing to the existence of numerous rapids and cataracts, of which that at Schaffhausen, 70 feet in height, is the most remarkable. At Bâle the river trends to the north, and flows in that direction over a long flat plain to Mayence (310 miles from the sea, and 240 feet above sea level), at the confluence of the Main. In this part of its course floods take place annually, but since 1840 this evil has been greatly remedied by the formation of a navigable channel varying from 3 to 30 feet in depth, with high embankments confining the stream to a width of 807 feet. At Mayence the river again turns west along the south slopes of the Taunus, and at Bingen, where the navigation has been improved by the removal of rocks which formerly impeded the course of the river, it once more turns north, entering a narrow defile which its quits at Bonn to wind westward over a portion of the great German plain to Emmerich, a frontier town a little above the head of the delta. How the Rhine then breaks up into Rhine and Waal, Rhine and Yessel, crooked Rhine and Lek, and finally reaches the sea through several mouths on the coast of Holland, can only be well understood by reference to a large map of the Netherlands.

Between Mayence and Emmerich the average summer width of the Rhine is 1,300 feet. and its mean navigable depth 8 feet. At certain places, at extreme low water, in dry seasons, the available depth is not more than 2 feet, in spite of the large sums of money which have been spent by the German States during more than half a century on regulation works of magnitude, comprising dredging and blasting operations, and the construction of those massive parallel draining dykes and groynes which are so noticeable to the eye of every traveler between Bonn and Bâle.

The principal tributaries of the Rhine on the right bank are the Neckar and the Main, the latter of which is navigable for barges over the last 200 miles of its course. The Moselle on the left bank rises in the Vosges, and becomes navigable at Pont-à-Mousson in France, but is almost useless for navigation on account of its very tortuous course and of its shallow bar where it joins the Rhine at Coblentz.

There is another tributary of the Rhine, however, of small volume, but formerly of great importance, which, on account of its celebrated coal measures, great industrial resources, and certain physical peculiarities, deserves especial notice in any sketch, however slight, of German waterways. I refer to the River Ruhr, which joins the Rhine on its right bank near Duisburg, between the river ports of Dusseldorf and Wesel. The Ruhr is the water-road from the Westphalian coal districts to the Rhine. Its drainage basin, including that of its tributaries, the Lenne, Ennepe and Volme, is 2,000 square miles. Its minimum discharge is 300 cubic feet per second, and its maximum 58,245 cubic feet per second, or two hundred times more than its minimum volume—a very abnormal relation indeed. The navigable length of the Ruhr is 46 miles and its average and minimum widths are 164 and 68 feet respectively. The river has eleven locks, 147 feet long and 18 feet 6 inches wide, and the barges traversing them draw 3 feet 6 inches, and carry 180 tons. During the period 1855–78, the navigation was interrupted either by ice or by floods, on an average from a maximum of one hundred and fourteen days to a minimum of twelve days. On this account, and on account of the low transit charges of the network of railways, the importance of the Ruhr has become almost *nil*. Thus in 1855 there passed through the Ruhr lock at Muhlheim 750,000 tons, and in 1878 only 46,800 tons. Projects for the improvement of the navigation of the Ruhr have been made, but are not likely to be carried out. If anything is done it will be solely with the view of diminishing the floods. This recent information concerning the Ruhr was obtained for me from official sources by my friend, Mr. Henry Gill, of Berlin, M. Inst. C. E.

In the first reach of the river above the delta of the Rhine, 12 miles below Emmerich, the width of the undivided river in summer is about 1,800 feet, and more than double that width in winter; the mean discharge being 89,000 cubic feet per second, and the maximum 341,000. At the apex of the delta ex-

tensive training works have been constructed to regulate the flow of the river after it leaves the German frontier, the object in view being so to distribute its volume, that in all states of flood, high as well as low, two-thirds thereof should be conveyed into the Waal, and one-third into the Lek or Lower Rhine. The navigable depth of the deltaic branches of the Rhine varies from 4 to 10 feet. An interesting account of the great works which have been constructed to regulate the flow of the various branches of the delta of the Rhine will be found in the Minutes of Proceedings Inst. C. E.

Steam towage is almost universal on the Rhine, and, as on some other rivers, a great difference of opinion exists as to the relative merits of paddle tugs, chain-tugs and wire-rope tugs. In 1873, a wire-rope tug company laid down the line from Bingen to Rotterdam and worked the upper section of 155 miles themselves, and in 1874, on the Neckar, five tugs were employed on a length of 56 miles. By means of canals the basin of the Rhine is connected with the basins of the Rhone and Saône, Scheldt, Meuse and Danube.

Although Germany possesses a length of nearly 17,000 miles of navigable rivers, or more than double the combined length of the navigable streams of France and the United Kingdom, it cannot be said to be rich in canals. In South Germany the Regnitz and Ludwig's canals, from the Main at Bamberg to the river Altmühl, an affluent of the Danube, were the only artificial waterways of importance until the annexation of Alsace-Lorraine. The North German Plain has several canals, the most important of which I have already referred to in describing some of the chief river systems of the Empire. In 1878 the total length of the seventy canals of Germany was only 1,250 miles, a very small extent when compared with the other canal systems of Western Europe.

HOLLAND.

Holland has the great advantage of holding the mouths of the Rhine and the Meuse, or Maas, and the Schelde, or Scheldt. Her means of river communication with Germany, France and Belgium are numerous, and the possession of a length of 940 miles of canals and 340 miles of rivers enables her, apart from her railways, which have a length of 1,130 miles, to carry on her large trade with greater facility of transport than any other European country, with the exception, perhaps, of Belgium, her industrious little neighbor on her southern flank.

Owing to the great improvements that have lately been carried out at the new mouth of the Maas at the Hoek of Holland, 18 miles from Rotterdam, vessels drawing 22 feet can already reach that port, and works are now in progress for the further improvement of the Lower Maas, which, when completed, will bring the total expenditure up to £2,500,000. Of the 3,765 vessels that made use of the new channel in 1884, 70 had a draught of from 20 to 21 feet, and 10 of from 21 to 22 feet.

By means of the North Sea and Amsterdam canal, a full account of which will be found in Mr. Hayter's paper on that great work, vessels drawing from 23 to 24 feet are able to reach Amsterdam direct from the sea by a channel 15 miles long, and from 65 to 105 feet wide at the floor line. This canal, which cost upwards of £3,000,000, and for which Sir John Hawkshaw was Consulting Engineer, and Mr. J. Dirks, Resident Engineer, has now almost totally superseded the third and earliest great maritime highway of the Netherlands, namely, the North Holland canal, 52 miles long and 16 feet deep, from the Texel to Amsterdam. This, the greatest work of its day, was constructed in 1819–25 by Blanken, at a cost of nearly £900,000.

The inland canals of Holland, which serve as arterial drains as well as for navigable purposes, are generally 60 feet wide at the bottom and 6 feet deep. In places where their extremities are connected with the sea, they are closed by massive flood-gates to keep it out when it rises higher than the canal. It is worthy of remark that within the natural sand dunes and artificial dykes which protect the coasts of Holland and Belgium from the encroachments of the sea, not only is the surface of the canal but the bed itself frequently many feet above the level of the surrounding reclaimed land; and it is an interesting fact that the surface-level of the North Holland canal between Buiksloot and Purmerend is 4 feet below mean sea-level.

Through the kindness of Mr. J. Dirks, M. Inst. C. E., Engineer-in-Chief of the Waterstaat, I am able to direct your attention to a very interesting map of the Low Countries which he lately forwarded to me "with the object of explaining," to make use of his own words, "our singular but historic system of nomenclature, our rivers being cut up into longitudinal pieces like an eel."

Belgium.

The surface of Belgium is generally level, and it is only towards the south-east that one finds a wild tract of country of small extent, but with elevations sometimes attaining a height of 2,000 feet. The principal rivers of Belgium are the Meuse and the Scheldt.

The Meuse rises at a level of 1,350 ft. above the sea, near Langres, in France, enters Belgium about 30 miles south of Namur, and on reaching that town receives its largest tributary, the Sambre, which almost doubles its volume. From Namur the course of the Meuse trends to the north-east, and continues in that direction to Venloo, passing Liege and Maestricht on the way. From Venloo it takes a north-west direction to Gorcum, where it joins the Waal branch of the Rhine. Its further progress to the sea is difficult to pronounce in a few words, and can be best understood by reference to Mr. Dirk's map. The total length of the Meuse, which is canalized at different places, is 580 miles, of which 460 miles are navigable.

This, by far the most important river in Belgium, although its basin has an area of only 8,000 square miles, derives its origin in France, 10 miles north of St. Quentin, at an altitude of 360 feet above the sea, and is navigable for more than four-fifths of its course. On arriving at Ghent, where it receives its chief tributary, the Lys, the tidal influence is first felt, and on reaching Antwerp the mean range of the tide is 13 feet 8 inches. At the mouth of the estuary (Flushing) the mean range is nearly 2 feet less, or only 11 feet 9 inches. According to information which I received on the spot in 1867, when charged by the British Government with a mission concerning an international question of engineering connected with the Scheldt, the scouring power of the tide at Antwerp is nine times greater than that of the fresh-water flow, the mean discharge of the latter being only 5,000 cubic feet per second over a width of 1,200 feet. Hence the great depth of the river at Antwerp of 24 feet at extreme low water alongside its noble range of commercial quays, which, for extent and accommodation are unrivaled in any other port with which I am acquainted. Thanks to its unique position at the head of a tidal estuary, which, like the Thames, has no bar at its mouth, to the abolition of the Scheldt dues, and above all to the foresight and liberality of the Belgian Government, which has spent £4,000,000 sterling on dock and river works since 1877, Antwerp has now become in many respects the foremost port of the continent of Europe.

Besides her 700 miles of navigable rivers, and 2,634 miles of railways, Belgium possesses a length of about 540 miles of canals, by means of which an excellent system of water communication exists between all the large towns and the chief sea-ports of the kingdom. By these artificial waterways, also, there is easy and cheap intercourse with Holland and with the chief towns in the north of France. On the authority of Mr. Von Borries, the cost of canal carriage from the Belgium coalfields to Paris was 0.29d. per ton-mile in the spring, and 0.34d. in the autumn of 1883, without paying interest.

REPORTS OF ENGINEERING SOCIETIES.

Engineers' Club of Philadelphia—*Record of Regular Meeting, June* 5, 1886.—Mr. J. E. Codman presented a paper on Calorimetric Tests of Boilers, from which the following paragraphs are taken:

Tests, for the quality of steam furnished by three different forms of boilers, in common use in Philadelphia, were made for the purpose of obtaining data to be used in the selection of additional boiler capacity.

The apparatus used for determining the quality of steam was a wooden barrel, large enough to contain about 230 lbs. of water, constructed for the purpose, the depth being considerably more in proportion to the diameter than usual. The steam pipe was carried to the bottom of the barrel, and a number of small holes drilled in the side, the end being plugged up. A side attachment was made by which the steam could be blown through the pipe, before turning into the barrel. The barrel was placed on a scale weighing to ¼ ounces, and 200 lbs. of water and 10 lbs. of steam used.

The temperature was taken with a Centigrade

thermometer graduated to $\frac{1}{10}$ degree. Observations were taken every fifteen minutes, and the condition of the fires, running of the engine, and other notes were made at the same time. It was found that the loss from radiation of the mixture was inconsiderable, as the temperature did not fall more than $\frac{3}{10}$ of a degree, Centigrade, in five or six minutes.

The first series of tests was made on the plain cylinder boilers, 30 ft. long and 4½ ft. in diameter, to the bottom of which were attached two mud drums, 22 ft. long and 28 in. in diameter. Boilers and mud drums were set in brickwork, and externally fired. The quality of steam obtained from these boilers varied greatly according to the condition of the fires and height of water in boilers. The greatest per cent. of moisture obtained was 17 per cent., with fresh fires and the water above the average height, reducing the steam space 30 per cent.

The second series of tests was made on what is commonly called the double-deck form of boilers. The lower cylinder was 6 ft. in diameter and 12 ft. long, containing ninety-two four-inch tubes. The upper cylinder 4 ft. in diameter and 13 ft. long, connected to the lower cylinder by three necks 14½ in. in diameter and 9 in. long. Boilers and drums were set in brickwork and externally fired. The heat and flame passed under the lower cylinder and through the tubes to the front of the boiler and returned under the upper cylinder to the stacks.

Samples of steam for the tests were taken out of the 14-inch main steam pipe leading to the engine, about 60 ft. from the boilers. The attachment for samples of steam was made with a 1½-inch pipe, about 12 inches long, cut in half longitudinally, tapped into the side of the steam pipe and carried inside so as to reach nearly across the pipe.

A 1½-inch stop valve was placed in this pipe, about 8 inches from the outside of the main steam pipe. Beyond this, the pipe was reduced to one-half diameter, and continued to the barrel. Tests were made every fifteen minutes during the day, and a sufficient number were taken under the varying conditions of cleaning fires, high and low water, and high and low steam, to give a fair sample of the average quality of the steam furnished in the ordinary working of the boiler.

It was noted that in no case was the change of condition in the boiler followed immediately by a change in the quality of the steam, an interval of from 30 to 45 minutes elapsing before the steam changed. This was, no doubt, due to the fact that the boiler capacity was far in excess of the amount required to run the engine.

The third series of tests was made on the marine tubular boilers, 10 ft. 10 in. long and 11 ft. 6 in. in diameter, containing two corrugated furnace flues and 188 3-inch tubes, with one steam drum 3 ft. 6 in. in diameter and 12 ft. 6 in. long, connected to two boilers. These boilers are internally fired and so arranged that the escaping gases pass off through the tubes, and under the drum, before entering the stack. Ten boilers were running and supplying steam for two 15-million gallon Worthington pumps.

Steam for samples was taken from the main steam pipe, about 15 ft. from the boilers and connection was made with a 2-inch pipe, and stop valve, reduced to ½ in. about 2 ft. from the main pipe and continued to the barrel. Steam from these boilers was found to show but slight variation, ranging from 9 to 6 per cent. of moisture.

The average of all the tests for each kind of boiler was found to be, for the

Cylinder	4.05 per cent.
Double-deck tubular	4.66 "
Marine tubular	6.91 "

Comparing the results as given in the annexed table, it is found that the cylinder boilers, driving to their full capacity, still furnished a fair sample of steam; while the double-deck boiler, doing only one-third capacity, furnished an average quality of steam; and the marine boilers, doing nearly the full capacity, furnished steam containing 2½ per cent. more moisture than either of the other two furnished.

Comparing with the evaporative efficiency of 5 lbs. of water per pound coal at given pressure and temperature for the double-deck and 6.3 for the marine boilers, and allowing for the 2½ per cent. more of moisture in the steam, the marine boiler will give 24 per cent. better results than the double-deck.

Comparing this with amount of work performed, it is found the marine boilers were doing 43 per cent. more work, showing an advantage in favor of the internally fired marine boilers, both in evaporative efficiency and quantity of steam furnished. In comparing the amount of steam furnished by each kind of boiler, the steam was computed from the indicator cards for double-deck and marine boilers, taken from the engines running at the time the tests were made. This, therefore, accounts for the small figure of evaporation given in the table, as only about 75 per cent. of the steam can be accounted for by the indicator card. For the cylinder boilers it is from the actual amount of water weighed and pumped into the boilers. Therefore, no comparison on the same basis can be made with the other boilers.

COMPARISON OF RESULTS BETWEEN MARINE AND DOUBLE-DECK BOILERS.

	Per cent.
Difference in favor of double-deck boiler in quality of steam	2.25
Difference in favor of marine boiler, in economic evaporation in pounds	1.25
Less, 2.25 per cent. for moisture in steam pounds	1.22
Per cent. in favor of marine boiler, in economic evaporation	24.
Difference in favor of marine boiler, in water evaporated, per sq. ft. of heating surface, in lbs. 0.4 per cent.	43.

Note—Same quality and size of coal used under all the boilers during the tests.

The Secretary presented, for Mr. G. R. Henderson, an article on the Taper of Steam Jets, issuing from circular orifices. Outlines were obtained by photographing different jets against dark back-grounds, and where they were sheltered from the wind, and measuring the angles

on the photographs. The following results were obtained:

With ¼-inch nozzle and 95 lbs. pressure, the half-angle was 11° 19′; ½-inch nozzle, 95 lbs., 11° 39′; ¾-inch nozzle, 95 lbs., 13° 5′; ¼-inch nozzle, 145 lbs., 12° 4′; ½-inch nozzle, 145 lbs., 10° 54′; ¾-inch nozzle, 145 lbs., 11° 27′. It will, therefore, be seen that the greatest difference between any two was little over 2°, the ¾-inch nozzle at 95 lbs., and the ½-inch, at 145 lbs., giving the maximum and minimum angles respectively. Inspection of the results also shows that the angle does not seem to vary according to any law relatively either to the pressure or size of nozzle. Taking the mean of the two extremes, we have an angle of 12°; the *average* half angle of the six experiments, gives 11° 44′, or, as the tangent of this angle is about .2, we may call the taper of the sides of the cone, 1 in 5.

Mr. Henderson acknowledges the assistance which Mr. W. E. Hall rendered him in making these experiments.

June 19.—The Secretary presented, for Prof. L. M. Haupt, the following:

"*Whereas*, It is proposed in the United States Senate to add an item to the River and Harbor Bill, amounting to one million dollars, for the purpose of beginning the work of improving the entrance to New York Harbor in accordance with the specific plan, approved by a Board of Engineers as stated in Ex. Doc. No. 78, House of Representatives, 48th Congress, 2d section; and

"*Whereas*, The plan as proposed involves a large expenditure of time and money, and is uncertain in its results, and

"*Whereas*, We believe the limitation of the expenditure to a specific plan would not produce the desired end in the most expeditious manner, it is therefore

Resolved, That in view of the general importance of radically improving the entrance to the harbor of New York, in the most expeditious, economical and effective manner, we would respectfully request our Honorable Senators and Representatives in Congress to urge the appropriation of the amount desired, but only on the condition that its application be not restricted to any special plan, but be opened to all competitors, upon plans to be subject to the approval of the Chief of Engineers, or of a Board of Engineers to be appointed by him."

With reference to the motion to adopt the resolution, Prof. Haupt called attention to the uncertainty, expense and great length of time which would be required to carry out the plan of the stone dyke from Coney Island, and stated that he believed the result would be merely to create a second contraction, similar to that existing at the "Narrows," with deep water at the exit, but that beyond there would reform a bar with not more than the present depth of water. The plane of tidal scour is limited, at that locality, to 24 feet, and unless some device be used to maintain an increased *bottom* velocity at ebb tide, he predicted failure. The dyke would violate a fundamental principle of harbor construction, by opposing great resistance to the flood wave, and hence diminish and weaken the ebb discharge, causing a shoaling in the lower bay and a cutting off and destruction of the northern channels. It would also render existing "aids to navigation" (light-house, etc.) useless.

He reaffirmed his opinion as to the practicability of utilizing the forces, acting so powerfully at the head of Gedney's Channel, to open and maintain the same, and believed it should be attempted by other means than by dykes or by dredging, before Congress committed itself to the plans proposed.

On motion of Mr. E. S. Hutchinson the preamble and resolutions were unanimously adopted.

The Secretary presented, for Mr. H. K. Lee, a table of Sizes of Chimneys, for the Reference Book.

The Secretary presented, for Mr. Fred. Brooks, C.E., of Boston, a table of Approximate Metric Equivalents, for the Reference Book.

The Secretary presented a letter from Captain Spencer C. McCorkle, wherein he states that the Superintendent of the U. S. C. & G. Survey had given his assent to the presentation to the Club, for publication and discussion, of the investigation which Captain McCorkle has made of Movement of Ice in the Delaware River in 1886.

Captain McCorkle was present and explained the scope of the paper and specially desires free and full discussion thereof.

Mr. Gratz Mordecai, author of a report on Railroad Terminal Facilities at New York, presented "Notes on the Investigation of the Movement of Freight and Passengers in Cities," and exhibited a large map—about 6′ × 10′—showing New York City and surroundings from Eighty-sixth street on the north, to Erie Basin on the south.

He said: "There is a great amount of information about every city scattered in its different public offices and in those of various corporations and firms, and my desire was first to combine and make all this information intelligible. I knew that every department of the city government was thoroughly acquainted with its specialty, and that the insurance companies, the directory men and many others had done what we would call—out in the country—an enormous amount of "field work," and that their field books were to a very large extent available. My first step was to get a 400 ft. scale map of the city, and I fortunately found one almost exactly to that scale, showing, however, only the streets. I converted to the same scale the different maps I found, in surrounding cities in the offices of the railroad companies, of the U. S. Engineers, the Dock Department and other sources, and in that way I compiled a fairly accurate map to that well approved scale for preliminary work, showing, in some detail, yet in a comprehensive way, the streets, street railroads, docks, railroad yards, tracks and facilities, freight houses, city markets, &c.

My next desire was to show something about the freight centers and the location, growth and concentration of the various trades. I placed on the original map the house number at the corner of every street (which was given in the directory); and from the business direc-

tory, taking the different trades and manufactures separately, I made lists of the numbers at which they were located on every street, and by this means located them on my lap, which shows, in different colors, the location of the retail dealers in food and manufactures, of the wholesale dealers in food and manufactures, and fixes the location of some of the various trades and freight centers, by special marks and numbers.

Appreciating that a city is both a center of consumption and a center of distribution, and knowing that an investigation of the movement of freight depends, for one thing, upon a knowledge of the local consumption, which must depend in part upon its population, I made my estimates of population (permanent and floating) in every ward of the city, and from them made an approximate estimate of the average daily movement of freight for local supply, and incidentally (from the reports of the different city railway companies) of passengers, and some of the approximate figures are given as follows:

Average daily passenger movement—1884, Elevated, 265,000; Surface, 505,000; Total, 770,000, or fully one-half the permanent population.

Average daily tonnage of freight (food, clothing, coal, etc) delivered directly to consumers south of Eighty-sixth street; 1885, 13,300 tons; 1895, 17,200 tons.

To be sure this movement varies in amount with the seasons, and these figures are only intended to give some idea of the average daily movement of freight for local supply to one destination.

I did all this work simply from my own personal desire to see what could be done, and doing it, as I did, without authority, my results, to be sure, are incomplete and my maps hardly more than begun, but I determined to my satisfaction,

1st. That it is possible to collect and combine in this way information of great value for the growth and prosperity of a city, and for the enlargement of its conveniences for works such as docks, railroads, markets, freight houses and other works.

2d. That an engineer, by patient investigation and the aid of such a map, combined with such detailed maps as the insurance maps, could make a most valuable report upon the methods and cost of handling, distributing, storing and selling the necessaries of life and the principal articles of trade.

3d. That the practical uses of such a report would be in the regulation of cities and corporate laws and in determining the location of public works and improvements

Here followed some general remarks upon the responsibility of the engineer in regard to "location" and the different influence he exerts in "country" and "city" work, as instanced in the cases of the N. Y., W. S. & B. Ry. through central New York and the Elevated Railroads in New York City.

"I cannot help closing with the plea that you do something to prevent the public convenience from being handed over, in an economic and engineering regard, to pecuniarily interested parties, and also to establish the rule that public franchises of all kinds for industrial purposes, should be reported on, not only by a corporation attorney, but also by a corporation engineer; for no matter how bright, far-seeing and progressive the promoters of new enterprises may be, it would seem that in public matters they should be officially controlled and aided by your experience and deliberate methods of study."

ENGINEERING NOTES.

WHAT is regarded as an engineering feat was accomplished a few days ago on the Great Western Railway, between Worcester and Hereford. The communication between these two cities was destroyed by the washing away of a large brick bridge over the river Tame, but within four days a temporary wooden structure of 65 ft. span had been erected, from the designs and under the superintendence of Mr Armstrong, C. E., of Hereford.

MESSRS. OLDHAM AND RICHARDS, of Manchester, have just patented a new pulley for driving planing machines, which requires no strap fork, and takes the place of the three pulleys usually required for driving, reversing, and loose running. This is effected by carrying within the pully a couple of friction cones actuated by a lever from the machine. The pulley itself constantly runs loose, and as the machine has either to be driven or reversed, one or other of the friction cones is brought into action. By this arrangement the driving strap constantly remains on the one pully, and a considerable saving of wear and tear is effected, whilst there is no loss of time in stopping the machine for changing the strap from one pulley to another, and the driving gear is brought within smaller compass.

A BIG CRANE.—A large steam crane, capable of lifting and manipulating weights up to 100 tons, has just been erected at the Alexandra docks, Hull. This is the most powerful steam crane possessed by any dock company in the United Kingdom. It has been satisfactorily tested with a load of 103 tons, in the presence of Messrs, James Taylor & Co., of the Britannia Works, Birkenhead, the makers of the crane, and of Mr. Hurtzig, C. E., the engineer, on behalf of the Hull and Barnsley Railway and Dock Company, to whose order the crane was constructed. After lifting and revolving with 103 tons, it was the next day put to a number of severe tests with a load of 65 tons, raising it at the rate of 6ft. 6in. per minute, and making a complete revolution—that is, the load passing through a distance of 283 ft. in 6 min. 50 sec. This powerful crane is an important addition to the appliances of the dock, which having a fine entrance and deep sill, is now not only well suited to the large steamers engaged in modern commerce, but is fitted for the reception of the ships in Her Majesty's service, and to deal with the shipment and unshipment of their heavy guns, boilers, &c, in an expeditious manner. It will enable shipbuilding firms of the port to compete for

Government work on equal terms with other ports, and will probably be first brought into use by Messrs. Earle's Shipbuilding and Engineering Company, who have commenced work on H. M. S. Malabar, having secured the contract for the refitting of that ship. The very large and heavy boilers of the belted cruiser Narcissus, now being built at Messrs Earle's works, will also be shipped under this crane. The crane is worked by steam power, steam being supplied by a steel boiler of Taylor's vertical type, tested with a pressure of 120 lbs. The head of the jib is 61ft. above the water level of spring tides, and has an out-reach of 29ft. from the face of the quay. The main features of construction are in the arrangement by which the center post common in cranes gives place to a large central pin, only subject to direct upward tension, the whole crane acting as a lever to raise it vertically. The jib, which is of the double cylindrical type, is of steel, while steel and wrought iron predominate in the structure throughout. Four sheaves, each 3ft. in diameter, are carried at the head of the jib, where the two steel tubes composing it meet. The load is suspended from the jib by eight falls of steel wire rope, composed of 222 wires, with a hemp core. The hoisting is effected by means of a large spirally-grooved barrel, taking the wire rope. There are two speeds of lift, the hoisting engines being horizontal, with double cylinders 12in. in diameter and 16in stroke. The two are for 100 tons and 50 tons respectively. For revolving, there is a pair of small vertical engines, actuating two sets of worm gear, one on each side of the crane, and two pinions which work into a large circular rack attached to the turned roller path. The fulcrum is the "live ring," containing sixty rollers, running on the cast iron and steel roller race on the top of the stone work. Ten or eleven of these rollers take the thrust at the foot of the jib at a time, constantly changing as the crane revolves, and the resistance is the weight of the masonry, secured by six massive, radiating, holding-down bolts, by which the center casting and pin are anchored. All the valves and levers connected with the crane are within easy reach of one attendant. The body of the crane is constructed of wrought-iron plates and framing, and is of great strength The whole is carried on a substantial foundation of masonry and concrete. The load trial consisted of 100 tons of steel rails, exclusive of the heavy slings by which they were suspended. The movable block and swivel is a very nice piece of workmanship, and it was quite easy for three men to twist round the heavy load while suspended. On the whole, this fine piece of machinery reflects great credit on the makers, and a finer crane does not exist in any port in England.—*Engineer.*

IRON AND STEEL NOTES.

An Antique Iron Helmet. — Two or three years ago some peasants digging near the banks of the Danube, on the Hungarian side, opposite to Belgrade, turned up a most beautiful and finely-preserved iron helmet. which, it will interest archæologists to learn, is neither more nor less than a *chef d'œuvre* of antique Greek work, of probably three or four centuries before Christ. It is scarcely necessary to say that works in iron of antique Greek or Roman origin other than corroded and scarcely recognizable fragments are of the utmost rarity. The specimen in question is in a wonderfully perfect state, scarcely, indeed, less so than that of a finely patinated bronze. It seems that it was found in the midst of wind-blown hillocks or dunes of dry, shifting sand; hence, probably, in some unexplained way, its exceptional state of conservation. Whether or not the skull of the wearer was found within it does not appear, but the helmet is in the shape of a complete head, the face, hair, and beard admirably modeled in *repoussé* or hammered work, finished with the chasing or graving tools in the most exquisite style. It represents a young warrior of about twenty-five or thirty, with an incipient beard and moustache—a Paris, rather than a Hector or Achilles; the eyes are open for the wearer to see through, and the lips are parted, leaving in like manner an aperture for respiration. Contrary to the arrangement of mediæval helmets, the upper part, or scalp, forming a skull cap – not the mask or visor—is hinged and movable, and it oversets the face. It was made to fit rather close to the head, probably leaving room only for a lining or padding of some soft substance, and it represents the natural hair of the wearer in finely-disposed, crisp locks. There is, however, at the summit, a small socket, evidently intended for a plume or some other ornament. The lower margin at the back of the scalp or skull cap is pierced with small holes, whence, probably, chain mail, to protect the back of the neck was originally attached. There are, however, no remains of ringed mail remaining The substance of the iron or steel is comparatively light and thin, but by no means flimsy or unsubstantial. In this respect, and also in some others, the helmet is not unlike certain steel Japanese helmets which have been brought to England of late years. These last also have visors in the form of human faces or masks, but they are always of wild, grotesque, and forbidding types. The Belgrade helmet, on the contrary, embodies a perfect ideal of classical Greek beauty.—*Bulletin.*

The Sampling of Pig Iron.—The question as to the best manner of obtaining a perfectly true average sample of pig iron, &c., for analysis, is one that has called for much attention from all chemists of iron and steel works, and on which a variety of opinions are held. An interesting and instructive paper on the subject was read at the meeting of American Mining Engineers, at Pittsburg, by Mr. P. W. Shimer, and from it the following notes are abstracted: If we take a sample of pig iron in the form of borings, such a sample consists of a mixture of particles of pig iron, with more or less finely-divided particles of graphite which has been separated from the iron during the boring. The amount of graphite thus present is in nearly all cases large enough to cause great difficulty in so thoroughly mixing the sample as to insure obtaining a perfectly uni

form and average portion for the actual chemical determinations; because such mixing is hindered by the great difference in weight, and also in size, between the particles of iron and those of graphite. Attempts were made to lessen this source of error by having the borings taken as fine as possible, so that the particles of iron should not be larger than those of graphite But this was not successful, as so much of the graphite was in the form of the finest powder. Duplicate determinations of carbon on samples so prepared, executed with the greatest possible care, always gave differences too large to be explained in any way, except by the inequality in the sampling. Nor were better results obtained when large borings were used, in the hope that the graphite which was detached from them during boring would be too small in amount to affect the results. It was not fonnd possible to obtain a proper mixture in any of the several methods of mixing which were tried. The differences were sometimes as large as 0.2 per cent. A plan was finally used which gave satisfactory results in all cases. The borings are carefully placed in a small porcelain crucible, or in a dish, and are thoroughly moistened with alcohol. For thirty grammes of borings two cubic centimeters of alcohol are required. The borings are then well mixed for some five minutes. The alcohol serves the purpose of making the graphite adhere to the iron during the time of the mixing. After mixing, the requisite portion for the actual weighing is taken out, dried, and weighed. It is stated that portions taken in this manner are always a true sample of the whole lot of borings, and give excellent results as to agreement, the differences between two determinations not exceeding 0 03 per cent.

RAILWAY NOTES.

In proportion to population, the greatest rate of railway increase since 1880 has been in Australia, but its mileage is still small, as is its population. In Europe nearly one-fourth of the railroad built since 1880 is in France, which has increased its mileage 3121 miles, or 19.2 per cent., in the four years. In proportion to population, it has now a larger mileage than any other European country except Sweden, Switzerland, Denmark, and Great Britain and Ireland. In proportion to area, it is behind Belgium, Great Britain and Ireland, Holland, Germany, and Switzerland.

The East Indian Railway Company has 1,036,527 iron plate, 178,313 iron bowl sleepers, and 2947 lineal yards of wrought iron sleepers. Of wooden sleepers, the company has down 3,073,559. The average age of all the sleepers in the roads at the middle of the last half of 1885 was 10.55 years. The permanent way of the East Indian Railway is laid with 2155 miles of double-headed rails weighing 82 lb. per yard, 1217 miles weighing 74 lb. per yard, and 1310 miles of steel rails weighing 75 lb. per yard. The average age of rails in way at the middle of the half-year was about sixteen years.

The construction of the Scinde-Hagar strategical frontier railway, British India, is making rapid progress. A section ninety miles long has been laid from Shen Shah, opposite Mooltan, on an alignment parallel with the left bank of the Indus. The rails are being laid at the rate of three miles daily. The Scinde-Pishin railway will, it is said, owing to financial pressure, not be carried for the present past Shah-Ahmed, the site of the proposed entrenched camp, but an iron bridge will be thrown across the Lora river in front of that position. It is possible that the delay may prove beneficial if it has the result of procuring more thorough examination than has yet been made into the respective merits of the tunnel scheme and of the Khojah alternative route by Muskhi, which, although longer, would avoid the difficulties of the Khojah range.

ORDNANCE AND NAVAL.

On the Deformation of the Bore of a Gun in the Region of the Obturator, and the Resistance of the Breech Block.—In an article with the above title the Author considers these questions. Few authors have dealt with the subject, and the theories of General Gadolin, published in the Russian Journal of Artillery in 1868, and an article by Captain Duguet, published in the Revue d'Artillerie in 1877, are reviewed and criticised.

The first-named treated the subject fully, and recommended the employment of hoops with longitudinal locking, to counteract the tensile strain exerted by the breech-screw on the interior wall of its seating; he also considered the deformation of the bore around the obturator. The general confessed himself unable to completely solve the problem, in the presence of the difficulties of analysis which presented themselves and moreover was obliged to rely on certain hypotheses which the author considers to be contrary to the truth. Thus he admits that the strain, transmitted by the screw to its nut, is spread uniformly over its whole length, and that the pressure produced by the outer hoop in the longitudinal direction is entirely transmitted through the whole thickness of the metal above the seat of the screw. He shows, it is true, that in the nut the greatest strain takes place on the first thread, but the Author considers that the formulæ given in the article are inaccurate, as he proceeds to show.

Captain Duguet, whilst taking accurately into account the conditions which occur in a piece submitted only to longitudinal strain, gives no results of calculation, and refers to the Russian article.

Considering, then, that the results up to the present time, as obtained by analysis, are very incomplete, no doubt from the difficulty experienced in the application of Lane's formulas, the Author, from recent researches, believes that he is in a position to treat the subject more accurately, and divides his study into three parts. (1) Is devoted to the establishment of new formulæ. (2) Treats of the question of deformation of the bore. (3) The resistance of the breech-block.

Having established new formulæ of displace-

ment, the Author proceeds to apply them to the consideration of part 2, for which he takes the case of a hollow cylinder, submitted to internal pressure, and closed at the ends by two plugs independent of the cylinder. One plug is considered as the projectile, the other as the obturator, which may be a steel cup, or the De Bange form. In the former case the pressure acting on the inside walls of the cylinder tends to increase its diameter, and if the cylinder be indefinite, the walls would be expanded in a line parallel to themselves; but by reason of a portion of the cylinder being behind a certain point D situated at the obturator, which portion is not submitted to any internal pressure, the line of expansion near the obturator will not be parallel to the line of the wall of the cylinder, but curved from the point D to a point A on the parallel line of expansion.

The length of this curve will depend on the interior pressure P_1, the original radius r_0, and the expanded radius r'_0 which is a function of the thickness of the cylinder by reason of the external radius r_1 and the pressure P_2 exerted on its surface by the hooping. Consequently the deformation will be so much less for a determined pressure P_1, as r_0 is less, r_1 greater, and P_2 still greater.

If the obturator were completely elastic, transmitting wholly the pressures in every direction, like liquids, over all its thickness, the curve of bending would have its origin at a point a little behind the obturator, but as it only transmits a portion of the pressure, the point D is taken as in a line with the front face of the obturator.

In the case of the De Bange obturator the point D is changed, because the elasticity of the pads allows the better transmission of the pressure, and it is probable that D is behind the same point with the cup form of obturator, it is taken as at half-way up the pad. Applying these considerations to the case of a gun, where the obturator is not only a gas-check but is firmly attached to the breech-block, the Author gives a diagram showing the theoretical deformation of the breech end, and applies the formulæ of elasticity to the determination of the form of the curve produced in the bore by the pressure P_1, from which he deduces the argument that, if the breech of a gun be hooped only in front of the obturator, the tendency to deformation in the seating of the breech-screw would be reduced as the pressure P_2 of the hoop would diminish the value of r_0. Other considerations compel hooping behind the obturator; so under these conditions, strictly speaking, a variable grip in the hoops, increasing in strength towards the section of the metal in front of the obturator should be given.—*Revue d'Artillerie.*

BOOK NOTICES

Publications Received.

Proceedings and Papers of the Institution of Civil Engineers:

No. 2070. The Theory of the Indicator and the Errors in Indicator Diagrams, by Osborne Reynolds, F.R.S., LL.D.

No. 2071. Experiments on the Steam Engine Indicator, by Arthur William Brightmore, Stud. Inst. C. E.

No. 2139. Injurious Effect of a Blue Heat on Steel and Iron, by C. E. Stromeyer, Assoc. M. Inst. C. E.

No. 2143. Blasting operations at Hell Gate, New York, by L. F. Vernon-Harcourt, M. Inst. C. E.

No. 2150. Water Purification, by Percy F. Frankland, Ph.D., F.C.S.

No. 2152 The Granada Earthquake, by Edward J. T. Manby, M. Inst. C. E.

No. 2184. English and American Railroads Compared, by Edward Bates Dorsey, M. Am. Soc. C. E.

Student's Paper, No. 200 Recent Researches in Friction, by John Goodman, Stud. Inst. C.E.

Abstracts of Papers in Foreign Transactions and Periodicals.

Transactions of the American Institute of Mining Engineers. Vol. XIV., June, 1885, to May, 1886.

Standard Practical Plumbing. By P. J. Davies. Vol. I London: E. & F. N. Spon.

This is simply an encyclopedia of household plumbing fixtures, and is made to include the processes of such adjustment to the dwelling as calls for the work of the artisan.

Most of the modern improvements are described and illustrated by good cuts, fully two thousand being employed in the book.

Of course such a volume (quarto, 360 pages) practically includes a complete treatise on sanitation of dwellings.

Monographs of the United States Geological Survey. Vol. IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey. By Robert P. Whitfield. Washington: Government Printing Office.

This is one of those additions to the literature of Paleontology, which students of Geology in all parts of the world will gladly welcome.

A sketch of the geology of the Cretaceous and Tertiary Formations of New Jersey begins the work, and will be read with interest.

Then follow the descriptions of the fossils in the order of their age.

The full-page plates, thirty-five in number, which illustrate the descriptive text are of that high degree of excellence that has of late excited the admiration of students abroad.

Ditmar's Tables for Chemical Calculations. Second Edition. By W. Ditmar, F.R.S. London: Williams & Norgate.

This is a very useful book for analytical chemists. The new edition contains a chapter on Gas Analysis that was not in the first edition. A very few typographical errors in the former issue have been corrected.

Considerable space is very properly given to "Explanatory Notes," as the calculations frequently involve operations in which laboratory workers are not necessarily expert.

The Table of Formula Values is a valuable aid to such computations.

The work is beautifully printed, and the tables are in antique type.

THE LUMINIFEROUS ÆTHER. By DEVOLSON WOOD, C. E., M. A. Van Nostrand's Science Series, No. 85. New York: D. Van Nostrand.

That a scientist is ready to maintain that the all-pervading æther differs only in condition, rather than its nature, from the familiar forms of matter, is a fact of sufficient importance to insure a demand for this essay by students of physical science.

After quoting the views of eminent physicists regarding the properties which presumably belong to the æther, Prof. Wood says:

"We propose to treat the æther as if it conformed to the kinetic theory of gases, and determine its several properties on the conditions that it shall transmit a wave with the velocity of 186,300 miles per second, and also transmit 133 foot-pounds of energy per second per square foot. This is equivalent to considering it as gaseous in its nature, and at once compels us to consider it as molecular; and, indeed, it is difficult to conceive of a medium transmitting light and energy without being molecular. The electro-magnetic theory of light suggested by Maxwell, as well as the views of Newton, Thomson, Herschel, Preston, and others, are all in keeping with the molecular hypothesis. If the properties which we find by this analysis are not those of the æther, we shall at least have determined the properties of a substance which might be substituted for the æther, and secure the two results already named. It may be asked, can the kinetic theory, which is applicable to gases in which the waves are propagated by a to-and-fro motion of the particles, be applicable to a medium in which the particles have a transverse movement, whether rectilinear, circular, elliptical, or irregular? In favor of such an application it may be stated that the general formulæ of analysis by which wave motion in general, and refraction, reflection and polarization in particular, are discussed, are fundamentally the same; and in the establishment of the equations, the only hypothesis in regard to the path of a particle, is—It will move along the path of least resistance." And furthermore, the author demands: "Granting the molecular constitution of the æther, is it not probable that the kinetic theory applies more rigidly to it than to the most perfect of the known gases?"

The analysis of the author leads to the conclusion that a medium whose density is such that a volume equal to twenty times the volume of the earth would weigh one pound, and whose tension is such that the pressure on a square mile is about a pound, and whose specific heat is such that it would require as much heat to raise one pound of it one degree (F.) as would be required to raise 2,300,000,000 tons of water the same amount, will satisfy the requirements of nature in being able to transmit light and heat 186,300 miles per second, and also transmit 133 foot-pounds of heat energy each second per square foot of surface normally exposed. This medium will be everywhere practically non-resisting and sensibly uniform in temperature, density and elasticity.

Like its fellow volumes of the Science Series, it is of convenient size for the pocket, and of such type as to render its reading easy by the student while traveling.

ELECTRIC TRANSMISSION OF ENERGY. By GISBERT KAPP, A. M. I. C. E. London: Whittaker & Co.

This is "a practical hand-book" *par excellence*—a book which will be read, studied, and used not by electricians merely, but by most engineers conversant with the English language. We would especially recommend this little treatise to those who are masters in matters appertaining to the mechanical transmission of power, for it is more than probable that electricity will soon take the most important place in the curriculum of experts in this particular subject. Until recently, problems on the transmission of energy to great distance could be solved by three means, principally, viz., by the hydraulic, the pneumatic, and the tele-dynamic means; each of these has its peculiarities, advantages, and disadvantages. Sometimes one of these systems was found more convenient or more economical than another, but neither of the three modes is universally applicable. Electricity may in many cases supersede water and air as regards economy, it will outweigh rope-gearing in points of convenience; but it is destined to find employment under peculiar circumstances where none of the other modes of transmission have hitherto been considered suitable.

Practical examples there are in sufficient number, and if the subject has not received the universal attention it deserves, the cause must be found in the want of a sober, systematic treatise. The literature on the electric transmission of energy has, up till recently, been rather unsatisfactory. Elaborate papers were read before scientific bodies, but they were mostly too elaborate to be of practical value. M. Marcel Deprez and others attempted to startle the world from time to time by announcements that energy amounting to several horse-power has been transmitted through several kilometres of telegraph wire; such facts, and the attendant mathematical reasoning, were very interesting in their way for the moment; but they did not serve to convey to the industrial man's mind the full meaning which the experimenters attached to it.

Most of the attempts of transmitting energy electrically were by the general public regarded as experiments of a purely scientific nature, and of but small importance. The reports in periodicals concerning many examples were often couched in language unacceptable by the matter-of fact engineer, and they were seldom sufficiently intelligible for the student. What we wanted was a systematic treatise, giving us a concise outline of the subject; a book which would lead us up step by step to a clearer conception of the whole business: a book which would teach us not only what has been done by others, and how they *did* the thing, but how we should do it ourselves. Mr. Kapp's hand-book gives us more than that; it goes a long way towards indicating ways and means of doing things better than they have been done before; and we venture to say that his book, small as it is, will have a most beneficial influence upon

the immediate development of an important industry. We differ from Mr. Kapp on certain points, but we are bound to give him credit for excellency of style, systematic arrangement, and remarkable clearance of definition. The language of the author, to say the least, is lucid, and he displays a peculiar gift in the choice of happy illustrations; the first chapter, consisting of about 40 pages, contains the essence of modern ideas on lines of force, the relations between mechanical and electrical energy, and a capital explanation of the fundamental and practical units of measurements. The author's description of an "ideal motor" and an "ideal system of transmission" we thoroughly appreciate as giving the student in few words the characteristic outlines of a grand lesson; he will by a careful perusal of these pages get a clear notion of the elementary principles involved, and it will save him at once from drifting into that hopeless confusion which is so often produced in the brain of the student, young or old, by the reading of certain obsolete text-books.

The second chapter has some allusion to the historical development of electro-motors, but this only for the purpose of illustrating certain principles. Too much space seems to be devoted to the description of the original Siemens machine and the effects of the dead points in the "shuttle-wound" armature; no less than seven pages of descriptive matter accompanied by tables of tests with two Griscom motors are given to this discussion. The results of these experiments are of little value, in so far as this type of machine has never been of much use, unless as a toy, and we have sufficient evidence to believe that the author must be possessed of ample material of a more practical character. There is a passage on page 64 which we do not appreciate: it says, "If it be absolutely necessary to use a motor of that class, the field magnets of which are either permanent steel magnets or are electro-magnets excited independently, the waste can to a certain extent be prevented by inserting into the *armature current* an electro-magnet which will by its self-induction steady the current." The italics are our own; we assume that "armature current" is a misprint and should read *circuit*, but the whole explanation seems quite unnecessary, as no one would think of resorting to similar means in order to attain the ends indicated. If the author had carried out experiments (of a kindred nature to those mentioned on page 65 and tabulated at 66) with a couple of motors of a type and size wherein the *secondary* influences do not absorb 70 to 80 per cent. of the energy supplied at the terminals, then he would undoubtedly have modified certain general conclusions which were evidently based upon the results recorded. Supposing we run two rationally constructed motors in series with a given load, current, and speed, it does not follow that by joining the same motors in parallel and using half the E. M. F. we shall get the same current and speed. If the current were the same, then the speed should be greater than before, because the resistance of a pair in parallel must be one-fourth of that of the same pair in series; and we know that the influence of resistance upon the speed of series wound motors is very considerable.

We admire, however, Mr. Kapp's method of developing a practical theory of the dynamo or motor; his formulæ are intelligible, capable of being applied by anyone possessing an elementary knowledge of mathematics, and above all they are reliable; we have found them so, and we know of none better.—*The Telegraphic Journal and Electrical Review.*

MISCELLANEOUS.

A New Constant Cell.—Mr. H. P. Laurie has devised a voltaic cell which he claims to be worthy of being considered a constant cell. It consists of a cadmium plate and a platinum plate: the exciting solution being of cadmium iodide with free iodine in it. The cadmium plate was, however revolved in the solution by clockwork at the rate of two or three revolutions per second. The electromotive force of the combination was about 1.076 volts. This is a convenient value for practical purposes as it is almost one volt. The movement of the plate appears to keep the electromotive force more constant, although the cell has been supplying a current, than if the plate had been kept still.

Conductivity of Resins.—M. Bartoli has ascertained that the ordinarily perfect insulators of the resin type become more or less good electrical conductors when heated to softness or melting, afterwards their conductivity increases with the temperature. A mixture of guaiacum with naphthaline, the latter a perfect insulator and of the same melting point as guaiacum- conducts much better than the resin alone, being much less viscous. Oxidised or acid constituents in the resin also increase their conductivity. Some always conduct very little, as Canada balsam, copal, mastic, and dammar; Chios turpentine, pitch, asphalte, colophonium, are moderately good conductors when soft or melted. Styrax, jalap, scammonin, dragon's blood, amber; the balsams of Peru, Tolu, and Copaiba; shellac, laudanum, aloes, myrrh, Venetian turpentine, are good conductors when melted.

A New Secondary Battery.—Herr Kalischer has devised a secondary element of iron and lead in a concentrated solution of lead nitrate. The iron anode is passive, and with currents not too strong becomes coated with coherent thick layers of black peroxide of lead, which protect the iron from contact with the liquid and from decomposition. The change is completed when gas is freely liberated at the anode, and the liquid gives only a slight precipitate with sulphuric acid. To prevent lead growths between anode and cathode, amalgamated lead in contact with mercury is used. In discharging, the peroxide becomes brown, and changes into monoxide, then into black peroxide. The electromotive force is from 2 to 2.5 volts, but sinks, when the current stops, to 1.8 volts. From its solubility in nitric acid the lead cathode must be occasionally replaced. Carbon can be used instead of iron.